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OBSERVATIONS ON THE TESTING AND USE OF PORTLAND AND NATURAL CEMENTS.

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[*Read December 12, 1906.*]

The present remarkable development in the use of cement is the direct outcome of the careful and persistent observations and experiments of our engineers, mechanical, chemical, and civil. There is not a structure of modern times built of natural stone or forms of burnt clay that has not been duplicated in cement. Cement is now meeting structural requirements hitherto impossible except by the use of iron, steel, and timber, and its advantages over the latter materials in the matters of cost, durability, and freedom from injury by fire and water are only just coming to be known. Time has shown that when cement is carefully selected and treated intelligently in the practical work of construction, enduring monuments are founded, to the honor and credit, not alone of the designer and builder, but, in justice be it said, to the pioneers and courageous supporters of this important industry in our country, who have persevered in face of many discouraging and adverse conditions until the American product is recognized as standard the world over.

While the rapid growth of the Portland cement industry since 1895, and the extended use of the material in all forms of construction, may be well taken as a tribute to its improvement and reliability, the better understanding and appreciation, not only of the users, but of engineers and architects as well, must also be

considered of the utmost importance. Hydraulic cements have been made and used for more than a century; and yet it has remained for investigators of comparatively recent years to throw much light upon the subject, and the light must be disseminated widely before the full benefit will be derived.

The adoption of a standard specification for Portland and natural cements during 1904 by the joint committee of the American Society of Civil Engineers and of the American Society for Testing Materials has proved a happy issue out of the maze of conflicting requirements which the manufacturer has met throughout the country in years past. It was perfectly natural, under such conditions, that doubt and suspicion of a product so little known should prevail among the uninformed. Before the adoption of the standard specifications, and even to-day to some extent, much conflict of opinion was found upon some of the most vital principles governing the acceptance of cement; each tester or engineer performing this duty was a law unto himself and exercised the full prerogatives of his official position in fixing requirements and interpreting results, oftentimes prescribing tests that were misleading and fallacious as an indication of quality, and which only served to vex and hamper the manufacturer; and in such cases an effectual barrier was set up between the very interests that have since combined and coöperated to the great benefit of all concerned.

In the absence of better information it may be natural for the user of cement to entertain with suspicion the statements of the manufacturer relating to the quality of a cement in question, but it seems obvious that with standard specifications and uniform methods of testing, combined with full and up-to-date information upon the results of the several determinations made, there would follow greater uniformity in the material, less opportunity for dispute, and a greater degree of confidence and mutual respect between men who are seeking the same attainments — excellence of material, design, and workmanship in all projects that mark the prosperity and progress of our country.

With an experience covering nearly eighteen years upon important hydraulic construction, I have found opportunity to observe many variable conditions affecting the requirements and

use of cement, and I know of no material entering into construction of which so much is expected that is subjected to the same or equal abuses; yet when a failure is recorded — happily very rare — how common it is to see the fault ascribed to the cement! The experienced and responsible manufacturer of cement believes in and encourages the intelligent testing of his product, and naturally of competing brands as well, and the time is not distant when he will *insist* upon tests being made in advance of use in reënforced concrete construction, or in other cases where he may be informed of either ignorant, careless, or dishonest methods, dangerous proportions, or the use of unsuitable materials to be combined with the cement.

An idea will obtain in the classroom, office, or laboratory which, if carried out or closely approximated in construction, would give excellent results; but how often this idea is forgotten or overlooked in construction, and crude—yes, cruel—methods of work are suffered! This can, under some conditions, be said even of cement-testing. Young men without previous experience or any knowledge whatever of the subject are sometimes selected for this work; and although they may have a high degree of intelligence, and be industrious and conscientious in their work, yet the best that can be said of such a selection is that it is more likely to result in causing a good cement to be questioned than in passing a poor one, although the latter chance is not remote; meanwhile, little consideration is shown the manufacturer or the reputation of his product.

Once asked to explain the difference in results obtained by two testers working together, using the same amount of water in mixing and following the same methods of molding, etc., I offered the somewhat parallel case of two cooks making bread from the same flour, same yeast, and same formula throughout, and yet the quality and appearance of the loaves would be quite unlike.

The personal equation cannot, perhaps, be removed in testing cement, but other conditions that vitally affect the results can be brought to a more uniform basis, and these in ordinary practice may briefly be summed up as the quantity of water used to produce a paste or mortar of given consistency, time and manner of manipulation, method of molding, temperature of water and air,

time and conditions of exposure in air and water, and rate of applying the load.

When tests are made under the instructions of the standard specifications by an experienced and skilled operator, they form a record valuable not alone to the work in which the material is being used, but to all users of cement who may have access to the results. Uniform tests, under a standard specification, serve to show:

First. Whether the material meets the standard or fixed requirements.

Second. Uniformity of the product tested.

Third. A comparison with other brands of the same material, which is invaluable at times when making a selection and computing the real relative net values.

Without a uniform specification and uniform tests thereunder, it is obvious that results could give no indication of uniformity of product, and a comparison with other brands or with the same brand tested at other points would be meaningless to a great extent. Training and experience are regarded as essential in any technical, mechanical, or professional work to produce results that are scientific, accurate, and dependable; the operator must know the full significance of his determinations or he will at times omit some detail or overlook a precautionary measure that may have a marked effect upon his results. Only trained, experienced men should be intrusted with the testing of cement on important public or private work where results are carefully tabulated and published in reports or otherwise circulated, and it is of great benefit and interest to all users of cement that we may have such results to refer to. The small or casual user of cement hardly finds it expedient or necessary to attempt a chemical analysis or test for specific gravity; in fact, when he is using a well-known and established brand he need feel little concern about this, and the tests for soundness, sand-carrying capacity (which he determines by tensile tests of sand mortars), time of setting, and fineness, all together have a bearing on the chemical proportions and specific gravity that means much to the experienced observer.

Tensile tests of *neat* cement are useless in determining the real relative strength of several brands of cement, and tests of

mortar of the proportion of 1 cement to 3 sand, by weight, should alone be considered in making comparisons. We *use* the cement with sand, not neat, and we want to know what to expect in our work. Many cements, both Portland and natural, give very satisfactory results in the neat test, but show marked inferiority compared with the best brands of both grades when tested for their sand-carrying capacity. Unless the standard Ottawa sand or crushed quartz be used throughout the test, we must recognize the fact that variable results will follow which are not due to the cement, but to the sand.

The effect of water in retarding the induration of cements and reducing their tensile strength, particularly at short periods, has long been known, and more or less information has been published as the result of experiments made.

The writer was led to make a series of tests on these lines during 1901, in somewhat more detail than anything he had seen published, and it is the result of this experiment, shown in the diagrams (Figs. 1 and 2) and in Table No. 1, that we will now consider. It may be stated that one man made the briquettes for the entire series, six for each period, at each interval in the amount of water used; the water used in mixing was at a uniform temperature of 63° F., and the temperature of the air averaged slightly under 70° F. and fluctuated between 50° and 75° F. Two briquettes of Am. Soc. C. E. standard form were gaged at a time, and beginning with the dry mixtures the molds were filled in three layers, each rammed successively until flushed, with a trowel. The ramming process continued until the mixtures became too soft, when the molds were filled by pressing in with the thumb and troweling. So far as possible the briquettes were allowed to set in air, under a damp cloth, for about two hours after taking the heavy wire, before immersion; this practice could not be followed uniformly, and some of the softer mixtures were allowed to set in air over night, and in a few instances the operator was obliged to wait until late in the night to complete his observations. In determining the rate of setting, the Gilmore needles were used. Care was observed to use the same sample of cement throughout the series, and this was taken from the storehouse of contractors engaged in the construction of large public work. The decimal

TABLE No. 1.

Showing Tensile Strength of Cements Mixed Neat with Different Proportions of Water.

Cement brand.	Water. Per cent.	Sieve Test; residue on			Wire; minutes.		Tensile Strength; pounds per sq. inch.					
		No. 50.	No. 100.	No. 180.	Light.	Heavy.	24 Hours.	7 Days.	28 Days.	3 Months.	6 Months.	12 Months.
"Giant" Portland.	13											
	14											
	15	0.15	5.4	21.2	12	207	371	655	875	941	720	787
	16	..	..	..	29	297	303	750	973	1 008	735	816
	18	..	..	..	80	355	260	649	773	831	645	748
	20	..	..	..	142	402	233	500	693	716	621	676
	22	..	..	..	268	473	184	546	635	658	601	589
	24	..	..	..	327	912	167	539	649	644	629	755
"Union" Natural.	23	0.1	4.6	10.2	13	32	212	251	252	311	275	356
	24											
	25	..	..	..	18	39	185	218	215	289	300	341
	27	..	..	..	21	42	150	188	220	257	272	314
	29	..	..	..	20	52	128	178	202	246	248	256
	31	..	..	..	21	57	112	173	199	224	259	309
	33	..	..	..	27	85	104	172	182	267	246	290
	35	..	..	..	38	137	93	121	178	260	286	319
	37	..	..	..	34	160	85	108	168	262	306	326
	39	..	..	..	67	233	85	119	202	252	371	400
"Atlas" Portland.	13	0.1	7.0	18.0	13	270	366	775	859	1 067	892	832
	14	..	..	..	18	303	404	780	891	972	852	781
	15											
	16	..	..	..	22	327	363	602	725	844	806	723
	18	..	..	..	15	383	308	570	723	785	728	724
	20	..	..	..	56	703	225	590	718	760	674	636
	22	..	..	..	52	833	166	554	649	731	643	604
	24	..	..	..	188	918	42	510	691	695	632	574
"Hoffman" Rosendale.	23	2.3	12.4	21.9	22	59	138	177	271	332	284	264
	24	..	..	..	..	78	125	141	264	342	309	310
	25	..	..	..	35	120	150	164	216	308	318	321
	27	..	..	..	49	143	117	116	194	305	345	272
	29	..	..	..	76	166	96	105	164	272	320	267
	31	..	..	..	117	212	72	72	159	270	371	225
	33	..	..	..	115	235	62	71	147	277	379	244
	35	..	..	..	127	400	50	64	112	245	318	315
	37	..	..	..	198	828	59	62	96	...	284	351
	39	..	..	..	260	1 057	54	56	85	...	355	364

Memoranda. — Results shown are the averages of six briquettes made.

scale of weights was used in gaging, the graduate glasses being carefully calibrated to agree, and the briquettes were broken on a Fairbanks machine of late pattern, the clips having roller bearings of composition metal.

Chemical analyses of the cements here considered were not made for this test, but the characteristics of the brands named are doubtless well known to many, and will be only briefly referred to. The Atlas and Giant brands of Portland cement both come from the Lehigh district of Pennsylvania, and, in their chemical composition, are in quite close agreement. The "Union" natural is also made from the Pennsylvania cement rock of the Lehigh district, is light in color, and its composition is quite unlike the "Hoffman," which is dark in color, being made from the magnesian limestone of the Rosendale district, New York. "Union" more closely approaches the Portland standard in composition, and differs from the "Hoffman" noticeably in its lime and magnesia content, having about 50 per cent. lime and 2 per cent. magnesia, while the "Hoffman" has about 36 per cent. lime and from 16 to 18 per cent. magnesia, which is characteristic of nearly all the New York Rosendale cements. The low magnesium content, together with the very fine grinding of "Union," cause it to be more active and quicker setting than "Hoffman," and this is well shown in the table and diagram, particularly in the wetter mixtures.

As might be expected, this difference in the cements would be in greater contrast when combined with sand in concrete mixtures than in neat cements; and, in fact, it was the dissimilar results in practical work of construction that led to this experiment. I regret that the experiment did not also include mortar mixtures in the proportion of 2 sand to 1 cement for the natural cement, and 3 sand to 1 cement for the Portland, wherein conditions more closely approximating the operations of every-day practice would obtain.

From personal acquaintance with a recent large work of concrete construction the writer is forced to the conclusion that when any reliance must be placed upon the cohesive strength of Rosendale cement within six months, or perhaps longer, depending upon the exposure and local conditions, great care must be exer-

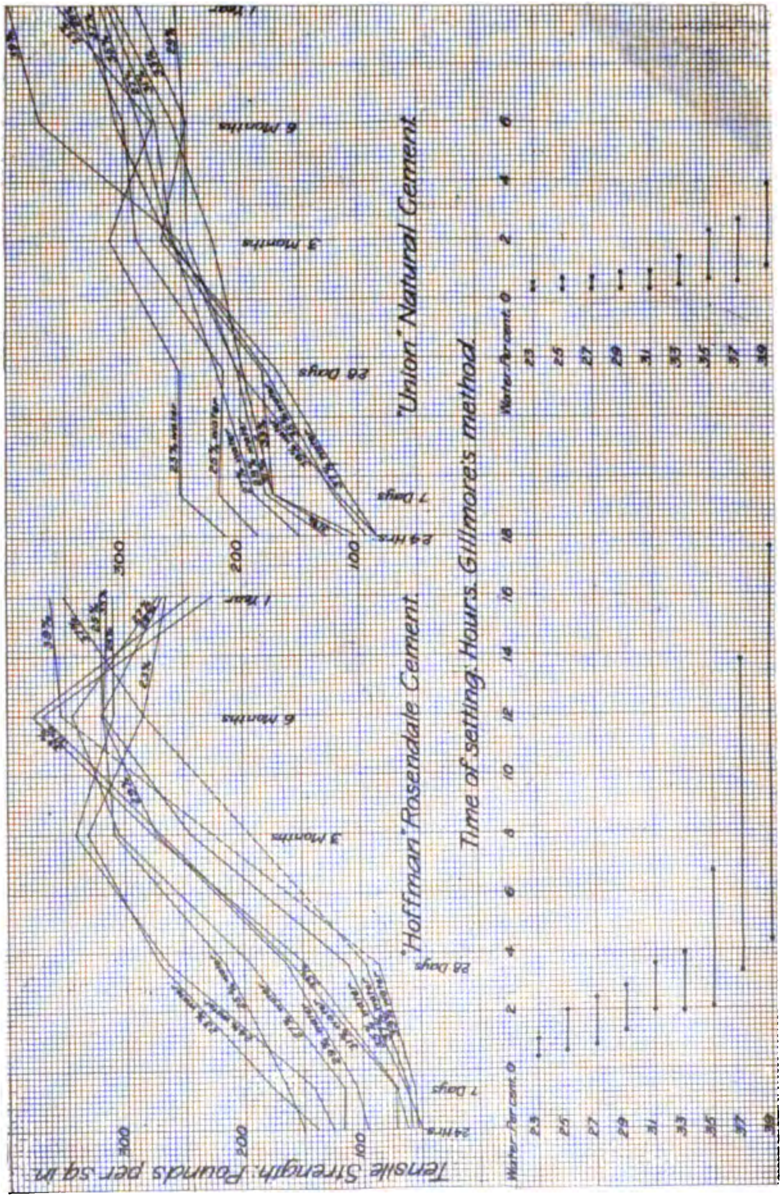
Tensile Strength. Pounds per sq. in.
"Hoffman" Rosendale Cement.
"Union" Natural Cement.
Time of setting. Hours. Gillmore's method
24 Hrs.
7 Days
28 Days
3 Months
6 Months
1 Year
100
200
300
Water Per cent.
23
25
27
29
31
33
35
37
39

FIG. 1.

cised in proportioning the amount of water used; or, in the present day of wet concretes, in selecting a cement that successfully withstands the deteriorating influence of an excessive amount of water.

In the diagram of tensile results (Fig. 1), the dryer mixtures of the "Hoffman" cement show superiority up to the 28-day period, at which time it is quite marked and uniform; the gain in strength between the 24-hour and 7-day periods appears slow, and grows slower as the amount of water is increased; the improvement between the 7-day and 28-day periods is better, but the rate of gain appears generally in favor of the dryer mixtures; the gain in all mixtures between this and the 3-month period appears quite uniform, and develops a rapid gain for the wetter mixtures; after the latter period inconsistencies develop, and between six months and one year only the 37 per cent. and 39 per cent. series show any appreciable gain, and the wettest mixture appears superior at the end of the year, the others generally showing a falling off in strength, for which I can offer no explanation.

In the "Union" cement series the dry mixtures generally appear superior at the 24-hour and 7-day periods, the rate of gain is quicker and quite uniform; as in the Portland cements, the gain in strength of the wetter mixtures is more rapid between seven days and twenty-eight days, the wettest mixture having passed four of the series next below, and all of the series being closer together than at the two earlier periods; at three months only the 23 per cent. and 25 per cent. series held their superiority, the wetter mixtures rapidly overtaking all others and being in close agreement, with the exception of the 31 per cent. series, which made a slower gain; after this period peculiarities develop for which no explanation can be offered, but the uniform rate of improvement is noticeable in all instances, and the results at one year are better in each case than at any preceding period, the 23 per cent. and 33 per cent. series showing a falling off between three months and six months with a good recovery at one year.

In the Portland cement series (Fig. 2) the rapid and uniform improvement between twenty-four hours and seven days is noticeable, but the dryer mixtures generally hold their superiority; this is noticeably uniform in the "Atlas" cement at all periods; the maximum strength was attained at three months,

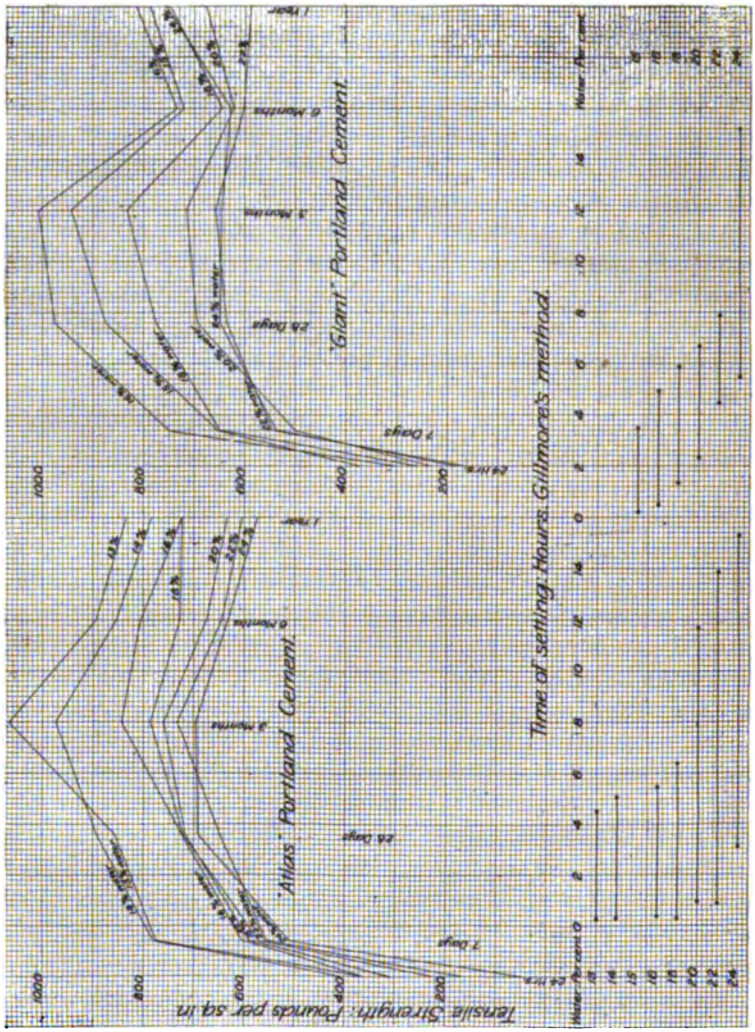
"Giant" Portland Cement.
"Atlas" Portland Cement.
Time of setting: Hours. Gillmore's method.
Tensile Strength: Pounds per sq. in

FIG. 2.

after which, and up to one year, there appears a steady falling off in strength; but from three months on the dryer mixtures are uniformly better.

The " Giant " cement also attained its maximum strength at three months, at which period the dryer mixtures also appear uniformly superior, with the exceptions of the 15 per cent. series; and judging from the results of this series throughout the test, it would appear that in this case there was not quite enough water used to perfect the crystallization of the cement. The " Giant " cement also shows a falling off between three months and six months, but a good recovery after this latter period in all but one series, 22 per cent.; and the wettest mixture, 24 per cent., passed the three series next below at one year, — two of them in fact in six months, — and between six months and one year it showed a more rapid gain than any of the other series.

The personal equation is apparent in these tests, as in any tests of the tensile strength of cements, but every effort was made to secure consistent and uniform results, and I will repeat that one man made the test throughout the entire series for the four cements named.

Cement or concrete construction, with or without steel reënforcement, is coming rapidly into favor, supplanting steel, stone, brick, and lumber in all forms of construction, and it is but natural that mistakes and failures sometimes attend the efforts of the inexperienced; and certain retribution is in store for the dishonest workers; but it is a remarkable tribute to this comparatively new system of construction that so few failures have been recorded during the phenomenal growth of the industry.

We find recorded failures in all styles of construction, brick, stone, steel frame, and timber, as well as concrete, but because of trade jealousies and the hostility of some labor unions, the failures in concrete construction are the best advertised at the present time. It is significant, however, that practically every instance of failure in concrete has occurred during construction, and has been chargeable to carelessness or incompetence. Unlike iron and lumber, concrete is not destroyed by fire, nor does it rust out or decay, but in fact becomes stronger and more durable with time, and the scores of splendid examples of this plastic con-

struction throughout the country are telling proofs of its merit and adaptability.

Low first cost is not necessarily ultimate economy, and if concrete did not perform its duty well and stand the test of time, other materials would surely supersede it. It is of the greatest commercial importance to all in the industry that quality should be a first consideration. You well know how the slightest imperfection in concrete work is pointed out by hostile interests as a sign of inferiority or failure, and a small crack which would be overlooked in brick work is viewed by the uninformed as a forerunner of sure and sudden collapse. Use only high-grade cement and select your sand with care, and beware of sand containing loam or clay; clean siliceous sand, ranging from fine to coarse, gives the best results; test it in combination with your cement before using. The ballast or coarse aggregate should also be clean, and of varying size in order to reduce the voids to a minimum. Gravel and igneous rocks furnish the best stone for concrete, much better than limestone for fireproof construction. For crushed stone, use a ¼-inch mesh dust jacket on the sizing screen; you will then have a more uniform product. The amount of dust varies with the size, shape, and character of the stone crushed, and also upon the rate of feed into the crusher, the speed of the crusher, and the degree of moisture in the stone. Stone dust, if clean, is better than most sands, but should be accurately gaged as sand, and more care is required to thoroughly incorporate it with cement because of the large percentage of fine material contained.

If crushed stone is stored or binned, as in most work requiring reserve stock, a more uniform mixture can be drawn from the bins when using, if the dust be excluded, since the latter serves to pack or cement the stone together, and alternating loads of coarse and fine will surely result in loading from heaps or drawing from bins.

In securing quality, thoroughness and care of mixing and placing concrete are of the utmost importance; *carelessness in placing will undo the work of mixing.*

Proportions of cement, sand, and stone will vary, depending upon the work to be done, but it is well to keep in mind:

First. That the stone voids should be a little more than filled with sand, and the sand voids a little more than filled with cement if strength is desired.

Second. That the voids in ordinary sand vary from 30 to 42 per cent., so that if leaner proportions than 1 cement to 3 sand be used, the cement will not fill the voids and the mortar will be porous.

Third. Accurate gaging is essential to uniform results.

A word as to consistency or amount of water used:

Wet concrete is the order of the day, and while I believe in using too much rather than too little water, still, in my judgment, much concrete is made too wet, and if in this condition much tamping, spading, or forking be done, the coarse aggregate will be driven to the bottom of each layer placed and a very unequal distribution of cement throughout the mass will follow. Except in the presence of very intricate reënforcement the mortar should be of a consistency to easily support the coarse aggregate and admit of light tamping. *Excess water serves to undo the work of thorough mixing.*

With a view of determining the variability of wet mixtures, the writer made the following test this past year:

Gang molds were placed vertically over each other, eight in all, to contain a layer 8 inches deep; the joints between molds were sealed with a thin layer of a mixture of white wax and tallow to prevent the escape of water. A high-grade Pennsylvania Portland cement was used in the proportion of 1 part cement to 3 parts of standard Ottawa sand, by weight, gaged with 20 per cent. water. Fine annealed wire (32 gage) was inserted between consecutive molds, and when the mixture had partially set these wires were used to cut the gang molds apart, and the operation was satisfactory in producing perfectly formed briquettes. The briquettes were then allowed to remain in the molds over night, under a damp cloth, and were then removed and immersed in water until broken.

The consistency of this mortar compared closely with that of much of the wet concrete now used, — dryer than some I have seen used in large work. When the molds were filled the mixture was churned and worked with a glass rod about ½-inch in diam-

eter. The following results (Fig. 3) are the average of three briquettes, a total of 48 being in the series; No. 1 briquette is from the top layer and No. 8 from the bottom.

The purpose of this experiment would have been accomplished in the test for one period alone, but it was deemed inexpedient to make the trial for any time short of one month. The inferiority of the briquettes in the bottom layers is clearly apparent, there being a maximum loss in strength of 117 pounds at twenty-eight days and 151 pounds at forty-five days. It would appear entirely reasonable to assume that a greater variation will be found in a 7-day test than in either of the above two noted.

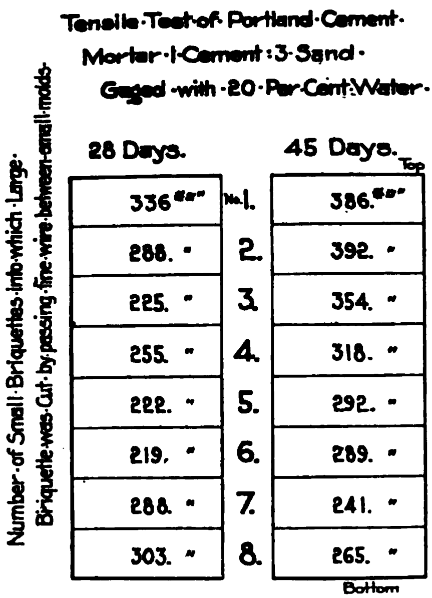

FIG. 3.

Concrete, to be of the utmost value, should be a true monolith of uniform strength throughout; this is of vital importance in beam, girder, and slab construction, and is not difficult of attainment.

This would seem to suggest that the idea of proper consistency is worthy of serious consideration, and further experiment, in the line of compression tests also, may bring forth interesting facts.

Table No. 2 and the diagram, Fig. 4, are also given showing the tensile strength of Portland cement mortar mixed in the proportion of 1 cement to 2 sand and gaged with different percentages of water, ranging from 8 per cent. to 20 per cent. Sand known locally as " Plum Island " sand was used. This is a dredged sand, very clean, selling at $1.60 per ton delivered. High-grade Pennsylvania cement was used. The results given are the aver-

age of three briquettes. Percentage of water used was determined on the combined weight of cement and sand. Briquettes were immersed in water until broken after remaining twenty-four hours in a moist air closet. The injurious effect of using too little water is plainly evident in the 8 per cent. series, and requires no further emphasis. Up to six months the superiority of the dryer mixtures, excluding the 8 per cent. series, is quite uniform,

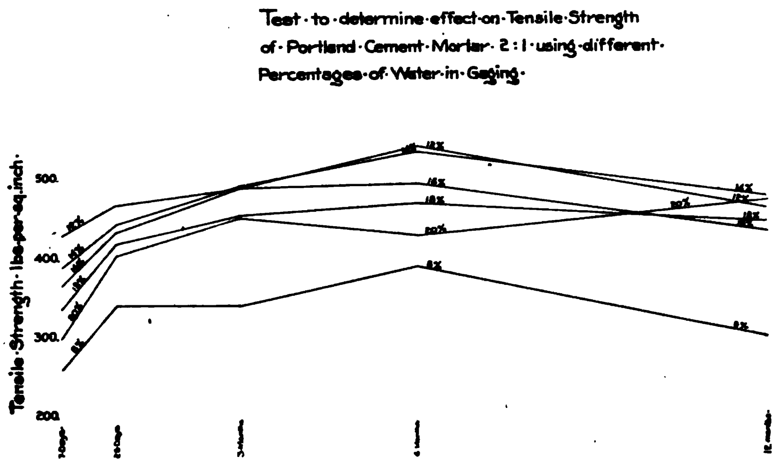

FIG. 4.

and it would appear that from 12 to 15 per cent. water would give the best results in a mortar of this composition, namely, 1 cement to 2 sand. Fourteen per cent. water will yield a very plastic mortar if properly tempered.

TABLE No. 2.

PORTLAND CEMENT MORTAR, 1 CEMENT TO 2 SAND.

	Tensile Strength, Pounds per Square Inch.					
Water — per cent.	8	12	14	16	18	20
Time of Test.						
7 days	261	433	392	368	338	301
28 ,, ...	344	470	447	436	422	407
3 months	344	490	494	491	457	454
6 ,, ...	392	543	536	497	472	430
12 ,, ...	300	463	478	434	446	474

It is gratifying to note the growing appreciation of the important part sand plays in all cement work, for in very many instances poor results are directly chargeable to the sand used. No cement will improve properly if mixed with very fine sand, and results will vary depending upon the characteristics of the fine material. It must also be kept in mind that an intimate mixture of cement and fine sand is very difficult to attain, and a thorough distribution of cement throughout the sand voids is absolutely essential to good results.

Sand that looks good is not always above suspicion, and the following instance will serve to show the importance of testing the sand before use. An important hydraulic work was begun last year in New Brunswick, and the contractors and engineers had congratulated themselves upon having what appeared to be an ideal deposit of sand and gravel for concrete work. The cement was thoroughly tested with standard sand and found satisfactory. When everything was ready, an active start was made, and considerable concrete was placed before any doubts arose; it would not set up, however, in a week's time (or longer, it proved), so the cement was immediately tested again, with favorable results, and then some of the sand was examined. On the washing test it was noticed that a slight opalescence was imparted to the water, remaining in suspension several days, but leaving practically no deposit on sedimentation. The cement was then tested with this sand before and after washing, and the trouble at once located. The sand and gravel were both washed thereafter, and good results followed.

Table No. 3, on page 17, is added showing the tensile strength of cement mortars in the proportion of 1 part sand to 1 of cement, by weight, for Rosendale or natural cements, and 2 parts sand to 1 cement for the Portland. A siliceous sand was selected for this test, carefully screened to the sizes noted, and combined in the proportions given in the table. The test was made to determine the relative value of sand grains of different diameters, in combination with cement, and also to study the effect upon the tensile results of adding fine material.

Few unwashed natural sands are free of dust, of a loamy or clayey nature, containing high percentages of organic material,

TABLE No. 3.—Tensile Strength of Cement Mortar with Sand Grains of Different Diameters.

Results given are the average of six briquettes.

Sand gage per cent. used.				Natural cement mortar 1:1.								Portland mortar 1:2.			
				Water per cent.	"Union."			Water per cent.	"Hoffman."			Water per cent.	"Giant."		
No. 30.	No. 20.	No. 100.	Fine.		7 days.	28 days.	6 mos.		7 days.	28 days.	6 mos.		7 days.	28 days	6 mos.
100	..	..	..	17	156	193	352	15	115	163	314	10½	286	288	412
..	100	..	..	17	151	194	349	15	118	146	286	10½	294	331	473
..	..	100	..	17	153	187	340	15	91	110	257	10½	201	226	294
..	..	..	100	17	100	123	307	15	71	76	186	10½	129	159	223
80	10	10	..	17	154	210	358	15	94	124	301	10½	361	380	486
70	15	12½	2½	17	142	190	332	15	86	107	254	10½	301	303	428
60	20	15	5	17	143	192	342	15	83	107	285	10½	307	311	419
50	25	17½	7½	17	140	208	345	15	80	89	291	10½	391	400	538
40	30	20	10	17	133	197	362	15	90	82	296	10½	350	355	475
30	25	30	15	17	123	191	329	15	78	77	266	10½	362	359	478
20	20	40	20	17	128	199	318	15	66	73	285	10½	317	374	480
10	15	50	25	17	122	201	324	15	68	72	221	10½	291	354	488
50	..	..	50	17	108	193	317	15	62	70	239	10½	247	287	351
50	50	..	..	17	154	222	323	15	82	107	316	10½	440	408	542
50	..	50	..	17	150	210	344	15	78	88	290	10½	309	336	438
25	25	25	25	17	125	183	302	15	74	68	250	10½	279	337	447
	Crushed	quartz.					3 mos.				3 mos.				3 mos.
40	..	60	..	16	179	256	355	14	93	100	142	9½	257	331	351

Memoranda.—All proportions and percentages determined by weight. Natural sand used, first passed through No. 8 screen and residue excluded. No. 30 sand passed No. 20 screen and caught on No. 30 screen. No. 20 sand passed No. 8 screen and caught on No. 20 screen. No. 100 sand passed No. 30 screen and caught on No. 100 screen. "Fine" is clean white sand sifted through the No. 100 screen.

and in specifications calling for sand clean and sharp and free from fine material, the importance of excluding this deleterious agent is recognized, but it is not always possible to enforce this exclusion absolutely; and from mechanical analyses of a large number of samples, and casual inspection of sand in use at various points, I am satisfied that much sand is used that contains 5 per cent. of dust, and a good deal that carries as much as 10 per cent., and even more in some instances.

The fine material passing the 100-mesh screen used in this test was obtained from a clean, white, siliceous sand; and if, with increasing amounts of this material, a falling off in tensile results appears, it can in no sense be taken as a *measure* of what would follow by using sand containing a dust of loamy or clayey nature, but it is in a way suggestive. The cements used in this test were of the same sample as in the other tests previously referred to.

The sand mortar test is the true basis upon which to judge the value of a cement, and I believe the proportion of sand to cement should be the same as that employed in the actual work of construction. Unfortunately, this was not carried out in the above test of the natural cements for the reason that results were desired for comparison with results of previous tests in the same laboratory, in which the crushed quartz or standard sand was used in the proportion of one part sand to one of cement.

Explanation of the results is hardly required; it will be noticed, particularly in the case of the natural cements, how uniform and constant is the falling off in strength at the 7-day period as the amount of fine material increased. This tendency, in the case of Union cement, disappears at the 28-day period, at which time rather remarkable uniformity is found in all the combinations, except the 100 per cent. fine; serious retardation in the improvement of the Hoffman, with the increase of fine material in the sand, is noticed between the 7-day and 28-day periods, the mixtures containing over 5 per cent. fine remaining almost latent for this time, three of the combinations showing an actual loss, while four make a small gain, the average gain being 2 pounds; a rapid recovery is found, however, in these combinations between the 28-day and 6-months' periods, and it is to be regretted that longer time tests were not made.

A tabulation of the results, excluding the series in which all fine and crushed quartz were used, is herewith given:

	7 Days.			28 Days.			6 Months.		
	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.
Hoffman......	84	118	62	99	163	70	277	316	221
Union	139	156	108	198	222	183	336	362	302

The effect of the fine material upon the Portland cement is not so noticeable, even at the shortest period, except in the series with 100 per cent. and 50 per cent. fine, and no parallel can be drawn between the test with Portland cement and the results with Rosendale cement, using the same combinations of sand.

Cement users are coming to select their cements with more discrimination than ever before; their increased knowledge of the subject, and the more extended use of the material, show this to be necessary, and the natural result, owing to the struggle for commercial supremacy among the manufacturers, will be a better and more uniform product.

The chemistry of cement is an intricate problem, and an academic knowledge of it without sufficient practical experience has resulted and will result in much trouble to the manufacturer and user as well.

It is well said that " Experience is the best teacher."

DISCUSSION.

Mr. Frank L. Fuller. I have had some experience in the use of concrete in the construction of reservoirs, mostly covered reservoirs, and its superiority in that kind of construction is very great. With brick and stone fixed methods of construction must be followed, for the material can be used only in certain ways, but with concrete we have a wider range. It is also true that to a greater degree unskilled labor can be employed, and this means a reduction in the cost of the structure. I think that better reservoirs can be constructed for the same amount of money, of better design, and of larger capacity, than could be built several years ago, even when prices of labor were less than they are to-day. This material is particularly well adapted for use in covering reservoirs and similar structures. The time for-

merly required to cover such a structure with brick can be reduced probably one half or even two thirds by the use of concrete, and the result will generally be better.

I think the point was well taken in regard to the separation of the cement from the aggregate in the case of too wet a mixture. Of course the tendency is, when the mixture is too wet, for the stone and sand to separate from the cement. Nevertheless, some work that I have done where the mixture has been very wet has been entirely satisfactory. A better face can generally be obtained to exposed work by using concrete that is rather wet.

PROF. WILLIAM P. MASON. Mr. President, I should like to ask for a little information with reference to a matter which came up in connection with the cement question not so very long ago. You will remember that Hillebrand and others published in the *Engineering News* some years back methods for the examination of cement from the chemical side, but, so far as I can find out, they did not differentiate between the combined silica and the mixed sand. Now the question which came up of recent date was whether certain cement bricks were up to the specifications. The specification called for a certain percentage of sand in the finished brick. I do not know how to make the determination of sand as against the rest of the silica except to separate them physically; and after the thing has once set it isn't an easy matter to physically separate the sand from the comminuted brick. The results are a good bit unsatisfactory. I would like a little information upon this point,— that is, the determination of sand in a set cement brick.

MR. LARNED. I will admit that there is a good deal of mystery about that, and it has feazed a great many very careful observers. An occasion for that determination arose in Boston within a comparatively short time, when the question of the proportions of concrete was raised by one of our city authorities, and some of our well-known experts were selected as a committee to examine the concrete and report on the proportions. The only way that I know of by which a close approximation — and it is only an approximation — can be made, is to determine the lime. We know that in the standard brands of Portland cement the pro-

portions of silica and lime are fixed within pretty close limits. They have to be to conform to the standard specifications. With the lime determined, and a proper allowance made for the silica to combine with the lime, then allowance can be made for the added silica, which is the sand. It is only an approximation, but it is the closest which can be made, I think.

There is one thing about consistency of cement which I did not touch on, which may be of interest to you. The bulk of concrete used in years past has been hand mixed, and in very many cases to-day it is necessary to so mix it. But I am very glad to see mechanical mixing coming more generally into use and being more generally required. It is a very difficult matter to combine sand and cement. They are naturally repellent of each other, with entirely different physical characteristics, and it takes vigorous work to combine them. You well know that in practical stone laying or brick laying operations the mortar tender is selected for that work who is a good, big, strong, husky fellow who can keep his hoe working in the mortar tub, and the more he works the mortar, the more he cuts it and churns it and whips it with his hoe or spade, the better condition it is in for the brick mason to lay his stone or his brick in. It is fatter. Now that quality of fatness means that the cement and sand are well combined, well incorporated with each other. In the case of hand-mixed concrete, where a dry mixture of cement and sand is first made, and then combined with the stone and the water added afterwards, the very first application of the water to that mixture means separation between the cement and the sand. You can see it, it is visible, and it is almost impossible in the presence of a coarse aggregate to bring the materials together again with shovels. They are, of course, knocked together in the hand-turning, but as a rule hand-turning is indifferent; the material is just rolled over. If it was slapped down, getting somewhat the same action that we get in mechanical mixing, it would be better.

To show how less water can be used and produce a concrete of quite a wet consistency, I might remind you of this: in mechanical mixing, if you use, for instance, twelve per cent. of water and hold it in your mixer for four or five or six additional

turns, it will compare very favorably in consistency with concrete in which you might have used sixteen per cent. of water and turned it out in a shorter time. It will be just so in hand mixing. You well know that concrete on the board oftentimes looks fairly dry, but by the time it is in the forms and subjected to ramming and spading and forking it flushes. That is due to the additional working. That same thing happens in the mechanical mixer and makes possible the use of less water.

Mr. Leonard Metcalf. One question occurs to me to ask Mr. Larned, and that is, if he made any determination of the character of the foreign material which was washed out by the water in this New Brunswick case of which he told us?

Mr. Larned. There was no analysis made. It appeared to be of a clayey nature. That was sufficient, and inasmuch as it seemed to be accountable for the trouble no further interest was felt in it.

Mr. William E. Foss. I should like to ask Mr. Larned whether he can tell us the cause of this little efflorescence which sometimes appears on brick masonry, whether it is due to the cement or the bricks or to lime, if they use it, or the coloring matter which is sometimes added?

Mr. Larned. Efflorescence is usually due to the washing out or dissolving of the alkalies in cement, soda, potash, and magnesia, and, as a rule, is more noticeable in Rosendale cements than in Portland cements, particularly the Portland cement of present manufacture. It is more pronounced, of course, in wet or damp locations, and has been successfully resisted by the application of waterproofing compounds, either in the mortar or on the exposed surfaces of the work.

Efflorescence sometimes originates or is added to by impurities in the brick, and occasionally it may be detected, not only through the joints of the brick work, but on the face of the work; this is due to absorption by the brick of the impregnated water from the mortar.

THE EXPLOSION OF THE SARATOGA SEPTIC TANK.

BY PROF. W. P. MASON, TROY, N. Y.

[*Read December 12, 1906.*]

On January 26, 1906, the cover of one of the four septic tanks of the Saratoga sewage plant was totally wrecked by explosion. The tank covered an area of $91\frac{1}{2} \times 51\frac{1}{2}$ feet, and was built of concrete, with a concrete cover supported by columns of the same material.

Six manholes pierced the cover, and these were closed by disks of cast iron held in place by their weight alone.

The explosive effect was uniformly distributed, the entire cover having been sheared from the side walls and from the supporting columns. Although the iron manhole covers were thrown to great heights, the heavy concrete roof of the tank probably did not rise over 10 or 15 feet and then fell back in a state of utter ruin.

At the time of the explosion, one of the local theories advanced to account for the disaster was the malicious introduction of some high explosive. Aside from the improbability of any one venturing to commit such an act, the character of the explosion renders that theory inadmissible by reason of the fact that a high explosive would have caused serious local shattering of some one part of the structure and not a wreck of great uniformity over the entire area of the tank. It is now pretty generally admitted that the cause of the accident lay in the firing of an explosive mixture of septic gas and air.

The question is, How was the match applied? The location of the plant is in a remote spot and there was but small opportunity for the act of some passing smoker to have occasioned the trouble. In the opinion of the writer the primary ignition was caused by phosphine.

We all remember the timeworn lecture experiment wherein that spontaneously combustible gas is permitted to bubble through water and burst into flame when the surface is reached. Could

a small portion of phosphine have been generated by the action of organic matter upon the phosphates present in sewage, then the flame following its escape from the liquid of the septic tank would surely have been sufficient to have kindled any explosive mixture of gases which might chance to have been present. Can such a formation of phosphine be looked for? It is certain that I should not care to attempt a chemical equation to represent the reaction, but it is equally certain that I have upon one occasion observed large bubbles of gas, each the size of an orange, rise from the river bottom off the New York City docks near the sewer outfalls and that such bubbles did burst into flame upon breaking the surface.

The suggestion that phosphine was the cause of the Saratoga septic gases becoming ignited seems reasonable, and the question arises, What is to be done to guard against a repetition of the accident?

Allowing the probable rarity of phosphine formation, yet the possibility of its appearing is ever present, and we consequently look for safety toward the prevention of an explosive mixture of air and septic gases. It is scarcely news to tell you that, given a combustible gas, the mixture of the same with air will not be explosive when the mixture is made in all proportions.

As shown by Kinnicutt, the septic tank gases commonly contain about 75 per cent. marsh gas, with the balance of practically non-combustible materials. For complete combustion, marsh gas requires ten times its own volume of air; therefore, on the above percentage composition, 1 000 cubic feet of septic gas would require 7 500 cubic feet of air to burn it, making the total volume of explosive mixture 8 500 cubic feet. Any decrease or increase of the above proportion of air would lessen the intensity of explosive power, until finally a non-explosive mixture would result.

Sealing of septic tanks, as practiced during the early days of the art, has been abandoned, and air can now gain admission to the space between the cover and the sewage. It would seem wise, therefore, to so order the ventilation of that space as to keep the evolved gases continually so diluted with air as to avoid the formation of an explosive mixture.

PLATE I.

THE SARATOGA SEPTIC TANK AFTER THE EXPLOSION.

DISCUSSION.

Prof. Leonard P. Kinnicutt.* I agree with Professor Mason in a great deal that he has said, and do not believe the explosion was caused by the introduction of an explosive into the tank. There is no question that there may be often an explosive mixture of gases in a septic tank, composed of methane generated from the decomposition of organic matter in the sewage, and of atmospheric oxygen, and the explosive force of this mixture when ignited would depend on the ratio that existed between volumes of the methane and the oxygen. The important question is, How did this mixture become ignited? Professor Mason believes that the ignition was caused by the formation of the phosphite of hydrogen, which is a liquid at ordinary temperatures, and which immediately takes fire when coming in contact with oxygen.

Theoretically, this explanation is a perfectly reasonable one. In sewage there is a comparatively large amount of calcium phosphate, and also what are known as reducing bacteria, — bacteria which take away oxygen from various mineral substances. For instance, we know that nitrates are reduced to nitrites and sulphates to sulphides, and there may be a variety of bacteria that reduce calcium phosphate to calcium phosphide, which would cause the formation of the liquid hydrogen phosphide. If this liquid phosphide were formed it would ignite spontaneously, and might thus have been the cause of the explosion. There is, however, one objection to this theory, which is, if phosphates in sewage are reduced to phosphides, we ought to be able to prove the fact by laboratory experiments. We can prove that nitrates are reduced to nitrites, that sulphates are reduced to sulphides, yet so far we have not been able to obtain phosphides from phosphates, and though I have made very many experiments with sewage sludge, I have so far failed to obtain any trace of calcium phosphide.

These experiments are still being carried on in my laboratory, and may yet give positive results. Still, until we are able by laboratory experiments to show that there are phosphate-reducing bacteria, a simpler cause of the explosion may be considered,

* Worcester Polytechnic Institute, Worcester, Mass.

namely, that the explosion was caused by a lighted match or smoldering cigar accidentally coming in contact with the gases in the tank. According to Professor Mason's account, one of the employees of the sewage plant had just stepped off the top of the tank when the explosion occurred. Of course this may only have been a coincidence, still I do not think that anything that Professor Mason has said precludes the idea that this man was the cause of the explosion, that he was smoking or had lighted his pipe while on the tank and had thrown either the smoldering ashes from his pipe or the still lighted match in such a way that it might have caused the ignition of the gases inside the tank. This explanation seems to me more probable than that the explosion occurred through the formation of liquid hydrogen phosphide.

President Sedgwick. I take it that Professor Mason only intended to suggest his explanation, and not to consider it as established or proved; but it does seem to me that his observation in New York is of very great importance. If a man has seen a river taking fire, he has a right to assume that there is something there which sets it afire, and it does seem to me that such an observation by such an observer ought to have great weight.

Mr. Eddy, I think, has had some experience along this line in Worcester, and we would be very glad to hear from him.

Mr. Harrison P. Eddy.* I realized some years ago, when I was trying to master the subject of chemistry under the instruction of the learned gentleman at my right [Professor Kinnicutt] that there was a good deal of theory about it, and to-day I am convinced that I was entirely right at that time, although it was then very difficult to convince him that that was true. [Laughter.]

This theory of Professor Mason's is certainly exceedingly interesting, and is worthy of very careful consideration and study; because, if what he suggests can happen, — if it is possible that that thing can ever happen, — we are up against a pretty stiff proposition, not only in connection with septic tanks, from which for safety we can omit the covers, but with our sewers and our cesspools and the deposits of mud under our wharves and under some of our buildings. It is a question if we shall be safe any-

* Superintendent of Sewers, Worcester, Mass.

where, except out in some place like the vicinity of the Saratoga disposal works where there are not many neighbors.

It does seem a little strange that we should have been dealing with septic tanks, where we have this gas all the time, and where we have the phosphorus all the time, for so many years, and that we never should have met just these conditions before. We are familiar with the fact that bubbles of gas come up on our septic basins, — large areas of the water are covered with bubbles of methane, — and why is it that they are not ignited? Why is it that we have never seen them burning in the open air? If there is a gas coming up which produces a flame, how does it happen that this thing can be constantly with us and yet never before have produced any effect which has been seen?

There are a number of things which it would have been interesting to have learned to-day about that explosion in Saratoga. We should like to know, for instance, whether the attendant was a man who ever smoked; whether he had a friend with him who ever smoked; whether he ever used a lantern in examining the tank, and various things of that kind. I presume the reply to all that might be that the man didn't smoke and that he didn't have any matches with him that day; but if he did it is very possible that he might have dropped a match which might have ignited a piece of paper or something which dropped into the tank. There are a great many possibilities.

When I was reading about this explosion some time ago I was very much interested, because I had mentioned in one of my reports the possibility of explosions in septic tanks, — not due to phosphine gas, however, — and it occurred to me that human nature is a pretty doubtful proposition, and any one who has had to deal with men in charge of filter plants, or in charge of gangs of men, knows that it is difficult sometimes to get at the real facts. To illustrate, I will just mention this incident which occurred some little time ago in connection with one of my foremen, who is a very trustworthy man, and whose veracity I ordinarily wouldn't question very much. I went upon the job one day, and after looking at him carefully and observing signs of intoxication, I said, " Pat, how many men have you got here? " He had some 30 or 40. " Well," he said, " I think I have got 14."

I said, " Pat, what is the matter with you? You have been drinking? " " No, sir, haven't taken a drop." [Laughter.]

Now that is the thing we are up against all the time in handling men; and while this Saratoga man may say that he did not have a match or lantern or cigar or pipe, there is still the human element which enters into the problem. I think Professor Mason's theory is very pretty, but I don't know but there is, at least, just as much ground for thinking that there might have been ignition from some outside source.

PROFESSOR MASON. Mr. President, I cannot help but wonder how high that man would have gone had he touched the tank off with a lantern or a pipe. You see there was no chance of anything getting in except through the manholes, and a man would of necessity have been on top of the tank in order to have dropped anything into its interior.

MR. JOHN A. GOULD.* I think that Professor Mason is right about this. Our chemist, Dr. Wing, has made numerous experiments trying to ignite explosive mixtures with a cigar. We have signs up all around our works, " No smoking allowed," but Dr. Wing has proved conclusively that it is impossible to light an explosive mixture of illuminating gas and air with a cigar, even when the cigar is at a bright glow; so I do not believe it would have been possible for a cigar, if it had been dropped into the tank, to have ignited the gas, unless it was more dangerous than illuminating gas.

PROFESSOR KINNICUTT. Speaking of the ignition of explosive gases, there is no question that an explosion in Lowell some six years ago of a mixture of carbon bi-sulphide and air was caused by a glowing cigar. And in experiments I made at that time a mixture of carbon bi-sulphide and air was easily set off, not merely by a lighted cigar, but also by a lighted cigarette. Furthermore, there have been explosions of septic tanks in England, and in two cases it appeared that workmen were smoking. Whether it was conclusively proved that the explosion was caused by these workmen I do not know, but it was so stated in the current literature.

MR. GOULD. I think the danger from smoking is in lighting

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* Assistant Engineer, Boston Consolidated Gas Company, Boston, Mass.

a cigar or pipe; that is, it is the match which does the harm. That is the danger from smoking around gas works. It is not from smoking, but from dropping a lighted match.

PROFESSOR KINNICUTT. I should like to ask you, Mr. President, whether there are any bacteria, so far as you know from your laboratory work, that will reduce phosphates?

PRESIDENT SEDGWICK. I don't know of any, no. I should like to ask Mr. Phelps if he knows of anything of the sort?

MR. EARLE B. PHELPS.* None have come under my observation.

MR. E. S. LARNED.† Isn't it a fact that they have a good many explosions in sewer manholes?

PRESIDENT SEDGWICK. I was about to say that explosions in sewers are not rare, but in these cases very frequently — although not always — men have been down in them. This suggestion of Professor Mason's, — which I take it he offers only as an hypothesis, a working hypothesis, and a very interesting one it is, — if investigated and followed up might explain a number of things. I can't myself get away from that observation which he made in New York, when he saw the bubbles come up and burst into flame, and it seems to me that until those who are opposed to his ideas can explain that observation in some way, his hypothesis has at least one leg to stand on.

MR. FRANK A. BARBOUR.† I do not know how exact Professor Mason's knowledge as to conditions under which the explosion took place may be, but my information at the time was that there were two men at work on the disposal field. One of these, the superintendent, was in the laboratory; the other had just come off the top of the septic tank. It is some time since I have given much thought to the matter, and I have had no opportunity of visiting Saratoga since the explosion, but if my memory serves I had a letter at the time stating that the second man had just passed over the edge of the embankment at the time of the accident.

When I left Saratoga after building the works — after being in charge of the plant for a year — arrangements were made to continue the observations of depth of scum and deposit in the

* Massachusetts Institute of Technology, Boston, Mass.
† Civil Engineer, Boston, Mass.

tanks twice each week. These measurements were taken with a Fowler sludge gage through the openings in the roof of tanks. It would, therefore, not be an unusual thing for a cover to be removed and for the attendants to be working around the openings in such a way as to permit the entrance of some external agent accountable for the explosion. I am practically certain that both of the men who were on the plant smoked, and smoked pipes, and I think it very possible that in some manner a match was dropped into the tank, perhaps in the act of replacing the cover, in such a way as to postpone the actual ignition until the attendant, luckily for him, had time to retire beyond the danger limit.

My feeling is, therefore, that the explosion was caused by some external agency — perhaps by a match; possibly by spontaneous ignition of oily cotton waste. At all events this explanation is indicated by the fact that one of the attendants had within a few seconds of the time of explosion been on top of the particular tank in which the accident occurred. There are four (4) tanks exactly similar in construction, and it is a remarkable coincidence, at all events, that with the same sewage treated for several years, and at the time of explosion all four tanks filled with sewage of the same character, if the accident was due to a process of chemical decomposition inherent in the sewage, the explosion should have occurred at this time and in just the particular tank over which one of the attendants had been working or passing. While not intending to deny the validity of Professor Mason's explanation, — and his observation made at New York is interesting, — the burden of the proof is certainly on him.

It is a matter of common knowledge that under such conditions, as stated by Mr. Eddy, it is difficult to obtain information from men who have passed through such an experience, and I am not surprised that no actual reason for the explosion has as yet been put in evidence.

As a matter of interest it may be stated that the roof of the tank was replaced as originally constructed and the tanks continued to be operated in the same way as before the explosion — the opinion of the local authorities apparently being that the explosion was due to some foreign cause. Smoking around the tanks is, however, prohibited.

PRESIDENT SEDGWICK. I am reminded of what is well known to us all, that explosions in sewers are generally regarded as explosions of illuminating gas which has leaked into the sewer; and in what I said a moment ago about sewers blowing up, I meant that the match might have been phosphine, or something of that kind, although the cause is generally traced to some man who has gone down with a lantern or has thrown down a match. Dr. Mason's paper is a contribution to our theory of these matters, and I am sure is of interest even to those members of the Association who haven't much to do with sewage, because septic tanks are now common, cesspools are everywhere, and sewer explosions are frequent, so that we want to know all that is knowable about these things. It is true that we don't know it all yet. There are reductions and combinations and permutations of chemical compounds possible under the influence of bacteria which we do not yet fully understand. It is well to keep an open mind in these matters, and we are very greatly obliged to Professor Mason for coming here and broaching this interesting hypothesis. I take it that he does not care to make it any more than that at the present time. Does he wish to add anything to what has been said?

PROFESSOR MASON. No; there is nothing to be added. That tank blew up, and something touched it off. It may have been a match, as has been suggested, but I believe that it may have been phosphine, and one reason why I so believe is because of what I saw on the New York wharf. The bubbles there burst into flame before my eyes; that is beyond peradventure. Now if anything of that kind should have occurred in the tank, it would have accounted for what happened. That such a thing did occur I do not venture to say; I offer it only as a suggestion.

MR. BARBOUR. I should like to ask Professor Mason what he thinks of the possibility of such bubbles coming through the existing depth of floating scum, which, in the preceding year, you could almost walk on? I do not know how it was at the time of the explosion, but when we were taking our sludge measurements in the preceding year it was with difficulty that we could shove the gage through the dried surface of this scum.

PROFESSOR MASON. Well, inasmuch as the septic gas passes

through the scum, the presumption is that gases of other kinds will pass as well. Septic gas passes into the space between the top of the sewage and the under side of the cover, and the phosphine gas, if formed, would naturally follow the same channel.

Mr. Phelps. Mr. President, I am fully as much interested in the remedy for this thing as I am in the theory as to the cause of it. Professor Mason mentioned two possibilities, only one of which he considered, — that is, either having too much air to allow of an explosion, or too little air and too much gas. I think perhaps Mr. Barbour could tell us which would be the easier condition to maintain. It seems to me it would, perhaps, be the better way not to ventilate the tank at all, but to keep it air tight and prevent the admission of air, rather than to attempt to thoroughly ventilate it.

Particularly does this seem better in view of the fact brought out by Professor Mason that a mixture of 10 parts of air with one of gas is required for an explosion. It strikes me that this is just about the mixture which one would get by ordinary ventilation.

Mr. Barbour. I think the ventilation of the tanks could be easily arranged; it certainly is a safe thing to do, and in future I shall make provision for ventilating the tanks, although there will be numerous instances where we will continue to use roofs as we are doing this year.

Experience has shown that open tanks are fully as effective as covered tanks, but it is to be remembered that in many places the appearance of the plant is the controlling factor. This was particularly the case at Saratoga, where the vicinity of the plant, while isolated, is a favorite resort of many of the summer visitors.

The covers on the tanks were simply of plate iron, about ¼ inch thick, and were not constructed so as to be air tight, being just set in a cast-iron frame. At the time of the explosion these covers may have been coated with ice in such a way that the gas was practically trapped under the roof. In certain experiments made in England, — described in one of the reports of the Royal Commission on Sewage Disposal, — no gas pressure in the septic tanks was found, the gas apparently diffusing itself through the masonry.

METER REGISTRATION.

BY ARTHUR N. FRENCH, SUPERINTENDENT WATER COMPANY, HYDE PARK, MASS.

[Read January 9, 1907.]

In reading the JOURNAL of this Association for December, 1906, I was interested in a little paper presented by Mr. George A. Stacy on "Pumping without an Air Chamber" and the discussion upon it. In that discussion Mr. Stacy spoke of a happening in his experience, when one of his patrons thought he had discovered a water meter which was registering when no water was passing through. It occurred to me then that some experiences of mine along that line might be of interest to some of the members of this Association who had not happened to meet with the same difficulties.

One experience which I had was along the lines suggested by Mr. Stacy's friend. I did have a water meter which registered cubic feet of water on the dial when absolutely no water was passing through the pipes. Of course we all tell our patrons that it is a physical impossibility for a meter to register without the passage of water, but I have had three cases in my experience when it has occurred, and I have experimentally caused meters to register without the passage of water. It is an unusual condition when such a result is accomplished, and to do this experimentally it is necessary to understand how it is done, and to provide the necessary conditions.

The season of 1899 was a very dry one, and my company found it necessary to add to its source of supply and to its pumping plant. A tract of land in another locality was secured, wells were driven, a station built, and a pump installed. The wells were 21 in number, 2½ inches in diameter, and the pump was a horizontal direct-acting compound of 2 000 000 gallons daily capacity. It was and is so rigged that it could be operated as a duplex pump, or by changing the valve connections either side could be operated by itself. It was found best to always run the pump in this latter manner, as the 21 wells would not furnish water fast

enough to make it profitable to operate the pump as a duplex. The water plunger is 14 inches in diameter and the stroke 24 inches. The pump is operated at about 32 strokes, or 16 revolutions per minute. As our system is that of direct pumping, with a standpipe for the excess, the operation of this pump makes a considerable amount of fluctuation in pressure on our mains and piping system. There is a surge at every stroke, and the pressure will vary about 9 pounds at the pumping station, and a mile distant the fluctuation of pressure will be about 3 pounds.

We began to operate this plant regularly in December of 1899, and some time in the following year one of our patrons called my attention to the action of the water meter in his house, which, he declared, was registering water when none was being used. He said that he could hear the meter operate in the dead of night. Complaints that " there is something the matter with the meter " are of such frequent occurrence that the statements of my friend were not taken very seriously. He persisted, however, and I went to his house. Everything was all right. The plumbing was tight, no water was being drawn, and the meter was not registering. I thought the incident was ended, but in a short time I saw my friend again, and he repeated his statements. I visited the house several times, and at last I found the meter actually in motion. I saw it go, and heard the piston thumping gently at about the frequency of the strokes of the pump at the pumping station. I satisfied myself that no water was escaping at any point in the house. All of the water piping and fixtures were in plain sight. I watched the meter and it registered one tenth of a foot on the test dial in a few minutes. After that I went there frequently and noted these same conditions. Then I took out the meter and set another of the same make. That would register just the same. I reversed the meter, setting it backwards, and left it there twenty-four days, in which time it registered forward 240 feet. The meter was of a type which does not revolve backward.

Of course we soon thought that the pulsations of the pump might be the cause of the trouble, but the only way in which these pulsations could produce such an effect would be through the existence of an air chamber of considerable capacity in the

piping of the house, allowing each stroke of the pump to compress the air and force a little water in through the meter, turning the pointer on the dial forward. In the interval between the strokes the air chamber would force an equal quantity of water back through the meter, which could not turn backward. I examined the plumbing for such an air chamber, but could find nothing which could possibly provide such a chamber except a hot-water heating plant in the cellar. The house stands on high land, and the pressure on the mains at that point is only 30 pounds. The hot-water heating plant of which I spoke is located in the cellar, and furnishes heat for a small greenhouse and for four radiators on the ground floor of the house. Water is connected with this plant from the house pipes directly, and is left on all of the time, and there is no expansion tank, so that there is always a pressure of 30 pounds on this heating system, and when it is fired up the expanding water must be forced back through the meter to the street main. It has no check valve. I think there was an air cushion somewhere in the heating plant, though I could not find one. Air may have been trapped somewhere in the return pipes where we could not find it.

After satisfying myself that the meter did actually turn without the consumption of water, I took it off and substituted one the piston of which will turn either forward or backward, and have had no further trouble there.

I was not quite satisfied with the knowledge gained by observing the above case, and decided to make an experiment. I therefore rigged up a rude testing plant at our new pumping station, where the static pressure is 98 pounds, and the fluctuation due to the stroke of the pump, 9 pounds. I took a kitchen hot-water boiler and mounted it in a hydrant house. I attached a pipe to the hydrant nozzle, set a meter, and attached the other end of the pipe to the hot-water tank, from which there was no outlet. A picture of the arrangement is shown in Plate I. When the hydrant was opened, the hot-water boiler filled with water to within about 9 inches of the top, that 9 inches being compressed air, making a splendid cushion. With this arrangement I tested several kinds of meters. It will be noticed that the meter in the picture is an old-fashioned plunger piston meter. That ran

beautifully under the test, registering one foot on the dial every $1\frac{3}{4}$ minutes, or 70 strokes of the pump. Another meter registered a foot in $32\frac{1}{2}$ minutes. I found that any type of meter which would turn backward would not register water under this test, but any meter which was so constructed that it would not turn when water passes through it backward, would register under that test. I found also that if a good check valve was set with the meter, no kind would register.

I have had two other cases of this same nature. In one case I found the air cushion in a long pipe running to a lawn hose faucet and another long line running to a stable, neither of which had been emptied of air when the water was last turned on.

Another rather mystifying experience which I have not yet fully worked out, but which I suspect is due to the same operation of the surge of this pump upon an air cushion somewhere in the piping system, is the peculiar action of a 2-inch meter on a fire standpipe. This is located in a block which has stores on the ground floor and flats on the two floors above. The standpipe is 2-inch, and has nothing connected with it except hose outlets on each floor, to which hose is always connected. There is no leakage, for if there was it would show on the floors. I have repeatedly examined the piping, and I believe there is no other possible outlet. No water has been used from this standpipe in the past six months, yet the meter now reads 1 847 feet *less* than it did six months ago. There is a regular decrease in the reading month by month. The meter is set correctly and is in good order, having been overhauled not long since. This meter is of the type which will turn either way; and I should like some member of this Association to explain how it can turn backward under the circumstances and not forward. It is possible that there is something in connection with the gearing which tends to drag a little when going forward, and allows free turning backward.

It is, indeed, a cold day when there is not some sort of a puzzle on hand in connection with meters. I once had an ordinary $\frac{5}{8}$-inch meter which all at once began registering backward at about ten times the speed at which it should register forward. On removing it and overhauling, I found that one wheel in the intermediate gearing had become loose on its shaft, fallen down, and

PLATE I.

APPARATUS FOR TESTING METER REGISTRATION UNDER FLUCTUATIONS OF PRESSURE.

engaged a different pinion below, reversing the travel of the dial hands, and driving them ten times faster.

Another ⅝-inch meter set on a dwelling-house service puzzled us for some time by registering up to about 65 feet and then going back and commencing over again. It seemed to have a certain prejudice against recording above 65 feet on its dials. We watched it for some time. The owner of the house fell under suspicion, though he didn't know it. On taking out the meter and examining it, we found in the train of gears attached to the pointers on the dial one wheel which had one missing tooth.

In several cases I have had a meter become set so that it would not turn, caused by the wearing of the end of a shaft in the intermediate gear, so that its pinion would drop down a trifle and engage two gears at once.

I hope none of the gentlemen present will form the opinion from this little paper that I am opposed to water meters. The contrary is true. In our plant about 40 per cent. of the services are metered, and if I were a magician the other 60 per cent. would be within the year. I would rather have this little paper taken as an indication that meter troubles come to every one, and no person in charge of a water-works plant which is beginning the work of installing meters should become discouraged by puzzling things in connection with them. The puzzles will be found solvable, and it will be found that there are not more of them than is the case with almost any machine.

DISCUSSION.

The President. Now is your chance, gentlemen. Here is something right off the bat [laughter], and if you can't catch it you are not in the game. I am sure Mr. French will be very happy to have a lively discussion. Of course we want to hear from the meter men.

A Member. Mr. Tilden has the ball, Mr. President. [Laughter.]

Mr. J. A. Tilden.* Of course freaks will sometimes appear in the best regulated families and among the best regulated

* Mechanical Engineer, Hersey Mfg. Co., Boston, Mass.

machines. I believe it is not an unknown thing for such a staid and reliable machine as a locomotive to start up of itself and run amuck. Somehow or other the throttle valve gets open, nobody knows how, and the thing runs away. Still we have a great deal of confidence when we ride behind one of these dignified and stately machines that we will get to our destination in due time, and the few occasions when they do run amuck do not discredit them in our confidence by any means.

There are in use in the United States to-day possibly somewhere in the vicinity of 2 000 000 water meters, and I venture to say without prejudice that, taken as a machine, taken as an instrument, taken as a class right straight through, they are reliable and are so regarded by the water works fraternity at large. These little things which Mr. French has told you about do happen, but it is very, very rarely. The conditions under which they occur are peculiar, and they have to be extraordinary. Mr. French has gone into the matter very carefully and explained to you just how these meters register when no water is passing through them. Of course that statement is not exactly true, for meters register because the water *does* pass through them, and they do not " unwind " the registration simply because they are of a type which can only operate by the water passing through them in the usual direction. Repeating, then, the meters of which he spoke registered because water did pass through them, but they didn't " unwind " when the water passed back through them.

There are several kinds of meters which will act in that way. It was at one time considered to be quite an advantage for a manufacturer to produce a water meter which was capable of registering in only one direction. Some inventors have gone so far as to put special ratchet devices on the gearing, so in case the meter was reversed by an unscrupulous water-taker, or a Chinaman [laughter,] he would have to pay for the amount of water which did go through, and couldn't unwind it so that the water company would owe him. I suppose if some of our good friends, the superintendents, were so disposed, they could tell of numerous instances where other types of meter, those which register equally well in either direction, have been maliciously removed from their connections and set in the wrong direction,

so that the registration has been very materially less than it was at the time of the previous reading, making virtually charges against the water department instead of charges against the consumer.

In systems where there is direct pumping, and where there is the liability of the formation of an air chamber, and one of the several kinds of that type of meter which Mr. French has described, it will work as he has shown. The air chamber in this particular case that Mr. French brings to your attention, that is, the one in the private dwelling house, is not far to look for. In a hot water system it is almost impracticable to fill the radiators completely full of hot water; there is no true circulation in the upper part of the loops of the radiators. The top part of every radiator is a true air chamber, so that with each pulsation of the pump there will be a marked flow of water into the system, and at each recession of the pump there will be a marked discharge from the hot water system back into the water works system; and a meter of that kind, — that is, the kind that won't unwind, — will go forward, as he says. He has gone so far and so carefully into the matter that he has explained fully how it may be avoided if you are ever up against that sort of a thing. Of course the simple presence of a check valve will prevent any possibility of working backward, when you are confronted with the air chamber problem.

In this particular case something is allowed which I think all water works superintendents will agree is extraordinary, that is, the direct connection of a hot water system in a private house with the water works system, without a check valve and an expansion chamber; in other words, allowing water works pressure to circulate throughout the hot water system, so that no expansion can take place without driving the water back into the water works system. The general plan, as you all know, is to provide an expansion chamber, or to go into a tank and then from the tank into the hot water system and then into an expansion chamber. The condition which Mr. French mentions was most extraordinary. In a great many places it would not be allowed, and I venture to say you would have to go a great way to find another such case.

He speaks of another type of meter. I might say here that I perhaps ought to have some reluctance to speak on this subject, because my good friend Mr. French is the superintendent of the water works in the town in which I live, and presumably no other meters are used in that town but my own. [Laughter.] I wish to say to you, however, that such is not the fact, and therefore my reluctance is not so great as it might otherwise be. Mr. French has had experience, as is stated in his paper, with a variety of types. There is no one type there which has gone through all his experiences, so I can speak on the subject in a broad way. He mentions a 2-inch meter which, due to the presence of the air chamber again, is steadily showing a less amount, month by month. That is a type of meter which will work both ways. That is, this particular meter is a current type of meter and will work either way, — by the water passing through it in the regular direction or with the water passing through it backwards. Now, being a current type of meter there is one direction in which it will work a little freer, a little easier, than it will in the other; that is to say, it will not register exactly the same amount of water forward that it will register backward, or *vice versa*. It so happens that this particular type of meter is a little more sensitive running in the reverse direction, so that while the meter is forced forward by the surging of the water against the air a certain amount, it recedes by the surging of the water in the other direction a little further back than where it started from in the first place, and the differential between the two is in favor of unwinding, which is the term Mr. French uses. Of course the condition is entirely abnormal there and is instantly relieved by the placing of a check-valve either in front or back of the meter. I don't know the name of the meter, and I am just talking in a general way because Mr. French said it was a current meter, and some of the current meters have this characteristic of measuring more in one direction than they will in the other.

The difficulties in connection with the intermediate gearing of which he speaks, that is, the wearing and dropping down of one gear into another, are common to all meters in which the motion of the piston is communicated to the dial by intermediate gearing. I think, however, I can say with confidence that it is

a most extraordinary occurrence. From my personal knowledge of and experience with thousands of meters, it is something which occurs, as you may say, only once in a generation. It has occurred, it does occur, but it is a most extraordinary freak, and occurs so seldom in the hundreds of thousands of meters that it may practically be disregarded.

The little incident about the meter which has such a strong dislike to register more than 65 feet without starting over again is really very funny. I can see how that might happen. I don't know whose meter it was, but it can happen to the dial of any meter made by any manufacturer. I apprehend it comes about in this way, and any one of you gentlemen can prove it by experiment. Suppose, if you please, it is a 6-dial meter; if you lock firmly the last dial, the last spindle, as it might possibly be by corrosion, and then undertake to wind it up, you get a very powerful spring action. One hundred thousand turns of the first spindle will make one turn of the last spindle, and with the last one rigidly fixed you can turn and keep on turning until the whole thing is a powerful spring, and the time comes when something has got to go, and that something is a tooth in the gear. The minute that tooth goes everything slips right back to its original place, everything goes right back to zero again, and proceedings start up as before until the broken tooth is reached and then the thing goes back again.

However, I am very glad that Mr. French does not bring up these things for the purpose of discrediting water meters, and I feel that neither as an associate nor as an active member do I need to stand here and apologize for what I believe, and what I am sure we all believe, is a most creditable record and a most creditable showing on the part of that marvel of mechanical ingenuity, the modern water meter. [Applause.]

Mr. George A. Stacy.* Mr. President, a few days ago my inspector came in and said, "We have got another mystery." Those mysteries go only as far as we make an investigation and search out the facts, and I can say that there has been no mystery about any water meter we have had yet that we have not been able to solve. In this case the trouble wasn't with a meter, but simply

* Superintendent of Water Works, Marlboro, Mass.

with the dial of the indicator on a plunger elevator, and the explanation was so simple that it shows how easily you can be fooled if you are not careful in making your investigation. This dial registers up to 10 000 000. The elevator has been in use perhaps four years and the indicator got up to several hundred thousand. The next time the inspector went there it registered 35. He came back and notified me, making the remark about its being another mystery. I said, " Well, the best thing you can do with that is to keep your eye on it; somebody has been monkeying with it." The next time he went there it had gone up from 35 to 95,000, and I said, " You had better take it out and bring it down here and we will examine it."

He brought it down. The cap that covered the face of the dial had been broken, and I set the indicator on the desk and began working it around, trying to find out if there was a slip in the gear or if a pinion had dropped down, but everything appeared to be intact. Taking hold of the hands and trying each one, and holding it up to a strong light, everything appeared to be in perfect order and in perfect mesh, and you couldn't start a thing anywhere. On most dials, as you know, in fact on all dials I had seen previous to this one, the hand on the end of the shaft is just put on and soldered, and if the solder breaks the hand becomes loose and will drop off at the least movement. But these hands were put on a little differently; a little more work had been put into them, and they were fitted on a little further; not exactly rivetted on, but so that the hand would turn clear around and not come off or show a break in the solder. They were stiff enough so you could move the gear back and forth and put about all the purchase on you would think ought to be put on to the hand without disturbing the joint.

The inspector came in at night and he says, " Have you found out the trouble? " I said, " No, I haven't; I guess we have got to look further than this." And just as I spoke I pressed pretty hard with my hand and I started one of the hands; and I found then that there were four of the high reading hands, which, by putting on pressure enough, I could keep turning around, but still they were tight enough to do the recording. The explanation was simply that, the case being broken, the everlasting small boy

had been playing clock with the thing, as we found afterwards; and he had set it so that sometimes they owed us and sometimes we owed them, and it got so we didn't know where we were. Thus the mystery was solved; and it was a very simple thing, like all the rest, when you get at the truth of the matter.

MR. EDWIN C. BROOKS.* Mr. President, speaking of connecting hot water systems directly with the water pressure, it becomes necessary in many apartment houses, where there is no room for a tank above the upper story, to put the hot water system for the house on to the direct pressure. Of course in Cambridge we discourage as much as we can the connecting of a hot water system direct, but nevertheless it is done frequently, and in order to give a satisfactory pressure of hot water on the upper stories of these houses it is necessary to do it.

We always calculate in setting a meter to make a canvass of the house and, if the hot water tank is connected directly to the water service, to put in a check valve. And there we often meet with opposition. We say to the householder, "We don't propose to furnish a drain for blowing off your hot water back into the main, and we don't propose to have you run hot water through this meter and ruin the discs, or anything of that kind"; so we put on one of the swing checks, and it has resulted in this: the cautious owners will go and purchase a 75-cent pop-valve and put it on to the hot water system and thereby make their plant a little safer than it would be otherwise. I think if check valves were more generally applied to all metered services it would result in a better condition of the meters, although I am free to say that we don't always have check valves which operate as well as we would like to have them. We endeavor to connect nothing but brass into the check-valve body, and in that way get rid of the corrosion that will always take place when an iron nipple is screwed into a brass fitting.

In regard to the registration of meters we all have complaints. An inspector will come in and say that a certain meter is not showing any use of water and we had better look into it and see what the trouble is; and we find that on some of the higher hands the pinions are stuck in the plates, and that they go up to a certain point

* Superintendent of Water Works, Cambridge, Mass.

where either the meter stops because it can't break the gear, or else a tooth of the gear goes. I must say that it is astonishing what power some of these little disc meters have for tearing things to pieces. I have often wondered at the amount of injury they can do to themselves, but still such is the fact. I think if our friends in the meter business would give us a meter clock, where the holes in the plates were bushed with something which would not corrode, a good many water works superintendents would rise up and call them blessed. [Laughter.] If you would go around and see the places where meters are set and the usage that they get, I think you would actually wonder sometimes that they did not stop from mere disgust at their surroundings. [Laughter.] But, as Mr. Tilden has well said, the modern water meter is a marvel of mechanical ingenuity and accuracy, and I think that any one who has to do with a large number of them will say that it would be hard to find a corresponding number of appliances, so intricately constructed as they are and put to such hard service as they are put to, that would do as well. [Applause.]

MR. GEORGE H. SNELL.* Mr. President, I have been very much pleased with this discussion and with Mr. French's paper, although I could not hear every thing that he said. All of our services in Attleboro are metered, and I sometimes think we know something about meters. From investigations we have made as to the effect of the vibration of the pump it seems to me impossible that a meter can turn without a discharge. There must be water going through in order to make a registration.

I remember a case about two years ago where a man who was a plumber and who used to repair our meters and thought he knew all about them, came and said he had a meter which certainly registered from the vibration of the pump. We went into his cellar and watched the meter for probably half an hour, and we found that it was registering; I think it registered some 10 feet during that time, possibly not so much as that. I said "There is a leak somewhere," but he thought it impossible. As the pipe ran underneath the concrete cellar bottom I suggested shutting it off, as there was a shut-off in front of the meter before the pipe passed

* Superintendent of Water Works, Attleboro, Mass.

under the concrete, and we found when it was shut off the meter did not register although we had the same vibration. What he did was to cut off his pipe underneath and piped overhead and in that way remedied the whole trouble.

The gentleman who first spoke referred to a locomotive running away; but it could not run away if the exhaust was stopped up; it would be impossible. The exhaust must be open to enable the engine to make a revolution. I believe those things should be considered as there is always some foreign trouble which we do not understand.

In regard to registration, we do most of our repairing; we have a good testing bench and a man who works continually on meters, and we find that most of the trouble is on the inside, either a little sediment, rust or some foreign substance, that stops the piston or the disc, as the case may be. Very seldom does the register bother us. My experience has been that while meters may run and register, they should be taken care of and cleaned out and repaired once in two or three years.

I saw one in Fall River a few years ago, which the man in charge of the meters had taken out and brought in, and there was really nothing left of it on the inside. He said the meter had been in for eighteen years, and I said, "How long do you think it has been registering?"

"I don't think it has registered," he said, "in the last ten years." [Laughter.]

I believe the main dependence of the water department, if you have a metered system, must be on the maintenance of your meters. In one city I know of, but which I will not name because I may not be able to state the facts just exactly as they were, they used to have a per capita consumption of 220 gallons per day. They investigated with the idea of increasing their water supply and employed an engineer who took the matter up, made an estimate of what the waste was, and as a result of the investigation they put in meters at an expense of about $35 000, and brought the per capita consumption down to somewhere in the vicinity of 85 gallons. The meters were set and no one knew anything about maintaining them or taking care of them, and in four years they had done nothing to the meters in the way of re-

pairing them, had not even taken them out when stopped, and as a result got back to 200 gallons per capita per day.

Now the only way to get income from the department, according to my idea, is to maintain the meters properly. Personally the only office work I do, outside of the correspondence and taking care of the necessary business, is making out the semi-annual bills. I charge on the ledger and the clerks in the office make the bills, and by being familiar with the charges, knowing the people and also the conditions, if the consumption is not as much as in previous months I invariably find the trouble. For instance, if they have been using $100 worth of water and it falls down to $65 worth, I notice from the meter readings that it has dropped from 15 000 to 12 000, 10 000, 8 000, 5 000, or 2 000, and that shows it is time the meter was taken out and changed.

I believe there should be some one at the head of every department who should be familiar with these conditions. We have 1 800 meters but, if there were 5 000 or more, there should be some one, even if it has to be divided into different sections, who will be responsible for each section and who will know the conditions.

In regard to connections where hot water is liable to back up to the meter, we had such a case in South Attleboro, — Sadler Brothers. They had a meter and paid about $25 or $26 each six months. When I came to the office it seemed to me that was a very small amount for boiler use and for a jewelry shop, and I inquired into it, and they said every time they read the meter it had stopped, so they simply got readings of a few hundred feet and made an average from that. After investigation we put in a check valve at our own expense and in the next six months we got $105. We kept along at $105, $115, $120 each six months, but later it stopped again, when a second check was put in with a valve between the two, so we could clean them, as sediment would get in them and let the water back. In that way we got $225 to $230 each year against probably $50 or $55 formerly.

MR. JOHN C. WHITNEY.* Nearly all of us must have had experiences in regard to meters registering when apparently no water was passing through, similar to those related by Mr. French. I

* Water Commissioner, Newton, Mass.

remember distinctly my first experience in that line. The complainant was a member of the water board. He came into the office and said that his meter was registering when no water was being drawn, and he knew it. Of course we received his complaint with polite incredulity, but offered to investigate the matter, and I was sent up to the house to make the investigation. The gentleman said he had to be away for a while and the family was not at home, but here was the meter and there was the plumbing system and I could make any investigation I chose and see what could be found. I went through the house and everything was tight, nothing running, not even a drop. I watched the meter and in the course of a few moments it moved up a tenth of a foot. I made another trip about the house to make sure that there wasn't something running, but no sign of trouble anywhere, and in the meantime the meter had moved ahead a tenth more. There was a shut-off on the pipe line within, possibly, 15 feet of the meter. I shut that off, made sure it was tight, that the water wasn't leaking by and watched the meter and in about five minutes it moved up another tenth. I found it was recording at the rate of about a foot and a half an hour.

The meter was one in which the registering mechanism can only move in one direction, of the ratchet-gear type, and was situated within half a mile of the pumping station on very high ground. The service pipe supplying the house was, I should think, 200 or 300 feet in length, and the pressure in the cellar probably not more than 10 or 12 pounds. There was no question whatever but this meter was working on pump pulsations. There was no air cushion and no way I could see by which the water could be forced through the meter and register, but it was doing it. We substituted for that meter one of a type which could record the reaction as well as the action, and after that there was no trouble.

Mr. John H. Flynn.* We have heard about what funny things meters are, but nobody has said anything yet about the men who read the meters. A friend of mine came to see me within six weeks and he said, "How much ought I to pay the city of Boston for what water I use?" I said, "How many rooms are you occupying?" He told me he was occupying three rooms in a

* Boston Water Department.

building. " How many fixtures have you got?" " Well, I have got a water closet and a sink." " Do you use water for any mechanical purpose?" " No, only for washing hands once in a while." I said, " I should judge somewhere about $7 or $8 a year would be fair." He said, " Well, I should judge that would be about fair; but how would $140 a year strike you?" I said, " That would be a little too high." He said, " I have got a private meter on the pipe I use, and for three quarters now I have paid $35 each quarter. Now, will you be kind enough to look at that meter for me?" I told him I would the first time I had any leisure; and as we are very busy in the water department, as you know, I had to wait a little before I could get a chance to go up and look at the meter. It seemed to be all right, and according to the way I read it he had used 27 cents' worth. I asked him who read the meter, and he said the janitor of the building. I asked him who made out the bills, and he said the janitor did. I asked him if he would be kind enough to let me see them, and he showed me the bills, each dated the first of the month ending the quarter, and I found that they all read just alike, that the number of feet he had used was just the same in every case, and it figured out that there was $35 for him to pay. So I saw the janitor and asked him who taught him to read meters. He said he learned how to do it from a book. [Laughter.] I said to him, " How do you make it that exactly the same amount of water is used every quarter?" He says, " Well, I always find the hands in about the same place." [Laughter.] Said I, " In other words, you think that the hands make a complete revolution?" " That is it," he says, " that is the only way it could happen." I took the meter out and tested it and I found that the meter was off only 500 per cent. in favor of the consumer. [Laughter.] The trouble simply was, that the gears had got twisted around in such a way that they didn't mesh very well and the meter would run along without turning the hands at all. I notified through him the manufacturers of the meter and they very kindly took it out. I haven't seen him since, but I guess he hasn't been paying quite so much as he used to.

MR. FRANK L. NORTHROP.* We had a funny experience once with a man who ran a bottling establishment. According to the

*Mechanical Engineer, Union Water Meter Co., Boston, Mass.

meter we owed him every month about $25. They were using water night and day all the time, there was a stable back of the building, and he had a great many fixtures in the building. We found that his system was all connected through the building. He had one ¾-inch and two 2-inch meters. After a while we found that the pipe going to the stable had a leak into a blind sewer, which no one could see, and the two 2-inch meters were furnishing water for the building and also for the sewer backward through the ¾-inch meter.

MR. J. C. HAMMOND, JR. I think, Mr. President, that if you should find our meeting dragging a little later, it would be a good plan for you to ask our meter friends to tell us who makes the best meter. If anybody asks me who has the best wife in my town I can tell him right off, but if anybody asks me who makes the best meter I confess that I am up against it. There are lots of good meters and some poor ones, but I had rather have a poor one than none. They are good scarers. [Laughter.] A red flag won't keep a man from being run over if he persists in standing on the railroad track, but if he has any brains he will keep off the track when he sees the red flag; I had rather have a tomato can and a dollar watch on a supply pipe than not have anything. [Laughter.]

EXPERIENCE WITH "UNIVERSAL" CAST-IRON PIPE.

TOPICAL DISCUSSION.

[*February 13, 1907.*]

President Whitney announced that an inquiry had been received from a member of the Association, who was unable to be present, asking for some information in regard to "Universal" pipe, and invited any one who had had experience with it to state the results that had been obtained.

Mr. John H. Cook. The Passaic Water Company of Paterson, N. J., has laid two lines of this pipe, 12 inches in diameter, across the Passaic River a mile or two above the town, and we have found it satisfactory. The reason we bought it was because it was convenient to lay under water. The pipe is made with a ground joint, the lengths are fastened together with bolts and lugs, and the pipe can be laid with unskilled labor. As a matter of fact, this line of pipe was laid by divers in a trench which was dug across the river under 6 or 8 feet of water in some places, and they could put it together very conveniently by means of the bolts and lugs. When the line was tested it was found to be tight and it has remained tight up to the present time.

At Little Falls, N. J., five or six miles up the river above Paterson, two or three miles of this pipe was laid by Mr. A. W. Cuddeback, a member of this Association, about two years ago, and I think he has found it satisfactory. It is a pipe which may be laid very rapidly by men who are not particularly skillful. I remember seeing up there one day a piece of trench which I should say was 250 feet long, and that length of 6-inch pipe was laid by two Italian laborers that day, and when tested it proved to be reasonably tight. I think they had to do some little adjusting afterwards, but not much.

The makers claim that the pipe may be laid considerably out of line without leaking, and that it may move or settle somewhat in the trench without leaking. I believe this pipe was bought at

Little Falls not because they preferred it, because it was a new thing then, but because they could get it very promptly, and the people who were putting it on the market were very anxious that more of this pipe should be laid.

THE PRESIDENT. Is lead used in the joints?

MR. COOK. No; no lead is used in the joints at all. They are ground joints. There is a male and female joint, and they are just put together and bolts fasten the pipe together by means of lugs which are on the side of the pipe. We laid two lines of 12-inch pipe across the river, and the pipe at Little Falls I think ranged from 12 inches down to 4 inches.

THE PRESIDENT. And that was also under a light head?

MR. COOK. No; the Little Falls pipe, I think, was at one time, indeed, has at different times, been under quite heavy pressure, because we drop the pressure through a regulator, or through a pressure-reducing valve, to this Little Falls line, but I think once or twice the reducing valve got out of order and put the total pressure on the pipes, and I think at that time they had no trouble with it to speak of. The Little Falls pipe system is now under a pressure of about 100 pounds, that is the pressure at the water company's office on the main street of the village. I think they have had one or two leaks, but no more than I should expect in any system.

A MEMBER. How long are the lengths of pipe?

MR. COOK. The lengths are short. As I remember, they are about 6 feet. Anyway, it comes in short lengths, and of course they have specials of different kinds which are contrived for this pipe.

A MEMBER. How does it compare in cost?

MR. COOK. It is much lighter, it does not weigh as much as ordinary cast-iron pipe, but the makers claim they use a much higher grade of iron. I don't know about that, however.

MR. COGGESHALL. Will it take the place of flexible-joint pipe?

MR. COOK. The makers claim it will, and it seems to be very satisfactory. As we laid it across the river, of course it was more or less out of line, and it was laid under the water by divers.

A MEMBER. What is the remedy for leaky joints?

Mr. Cook. I suppose it would be to dig up the pipe and tighten up all the bolts. I have had no experience beyond what I tell you.

A Member. As I understand it, the pipe you laid across the river was under about 6 feet head of water in the river?

Mr. Cook. Yes.

A Member. What pressure did you have on the pipe?

Mr. Cook. I think the pressure was 30 or 40 pounds, but the Little Falls pipe system was under considerably heavier pressure than that.

Mr. Charles W. Sherman. I remember that a few months ago some one, I think it was a member of the Association, told me of a case where he had used the Universal pipe across a marsh for a distance, as I remember it, of about half a mile. I can't remember who it was who told me, or where the place was, but he said he had found it entirely successful. It was easy to lay, and it obviated the trouble he would have had if he had tried to make lead joints in that wet locality.

The difficulty, if any, with this pipe, seems to me to be in the durability of the bolts. As I remember it, there are two bolts which draw the lengths together and make the joint, and so far as I know none of this pipe has yet been in service long enough to give any reliable data as to the life of these bolts. I should be somewhat afraid that after a few years this pipe, laid in a trench, would develop leaks which would be pretty hard to locate, especially with a joint every six feet. Of course they claim that if the joints are once drawn up tight and the earth thoroughly backfilled around the pipe, it is going to stay there and remain tight. I don't know how far I should want to trust that to be the case after the bolts were gone.

There is no reason, so far as I can see, why the joint should not be as tight when the pipe is new as in any pipe, and why the pipe itself should not be as durable as any pipe.

Answering Mr. Coggeshall's inquiry as to its taking the place of flexible pipe, I do not think it would take the place of a spherical jointed pipe which would be used, for instance, in laying a submerged pipe line from a scow, allowing it to sink as the pipe is jointed and thrown out. It would allow no such flexibility of joint as that,

but it does not have to be laid strictly to line and grade, as some of the ground joints of bell and spigot pipe would have to be. I would suppose that the deflection available in the pipe would be about the same as in the ordinary bell and spigot joint pipe.

THE PRESIDENT. I should like to ask Mr. Conard if he has ever had any experience with this pipe.

MR. WILLIAM R. CONARD. I have never had any direct experience with the pipe. I have seen it in one or two places, not in service, but where it has been exhibited and demonstrated for exhibition purposes more or less. I will say that it is cast horizontally rather than vertically, in 6-foot lengths. The finished portion, I think, of the male end is about an inch to an inch and a quarter in length, beveled, and the female end is not quite so long, possibly three quarters to an inch. After the bolts are drawn tight, there isn't much room for flexibility, and I should imagine when dampness got into the joint it would rust it up and make practically a solid line of pipe. What will happen after the bolts rust through, or what will happen when expansion and contraction comes on the line, is something I should judge the pipe has not been in service long enough to demonstrate fully yet. There was quite a line of it laid in Atlantic City, a year or two ago, for, I think, the Atlantic City Gas Company, all the way from 4-inch to 16-inch. I know some of it was as large as 12-inch, and I think there was some as large as 16-inch.

SOME OBSERVATIONS ON CAST-IRON PIPE SPECIFICATIONS.

BY WILLIAM R. CONARD, BURLINGTON, N. J.

[*Read February 13, 1907.*]

It may be well for me in beginning this paper to call your attention anew to a portion of the report of the Committee on Standard Specifications for Cast-Iron Pipe, presented December 11, 1901, which is as follows:

" The committee has conceived its duty to be not the recommendation of new processes, radical changes in existing specifications, nor even an unvarying list of weights for different heads or pressures, but rather a codification of the best present practice in design and manufacture in such form that, if used as a standard, pipe can be furnished by the manufacturers, and procured by purchasers,with more certainty and satisfaction than can be done at present, even with the most perfect individual specifications, and at the same time to be sufficiently elastic to allow, with a minimum of trouble, the incorporation of special ideas in an order for pipes.

" It is believed that standard specifications, to obtain general acceptance, must allow for the personal equation of the user. While the many difficulties attending the present individualistic methods are well known, the committee recognizes the futility of the adoption of a standard which, although securing uniformity, too closely limits individual freedom of practice.

" The variation in form and dimensions of pipes and castings from different foundries, and even in different lots from the same foundry, causes much trouble and expense in pipe laying. Special castings are the most troublesome in this respect, spigots often being too large or thick to allow sufficient lead room in the bell of the pipe, even if they will enter at all without chipping the bead. Different classes of pipe often cause trouble in the same way, especially when the different thickness of shell is secured by a change in the outside diameter.

" Unless drawings are furnished for special castings (which it is not always practicable to do, especially for small orders) one does not know the length or weight, or even if the castings will

come with bell and spigot, or bells all around. Sometimes reducers are sent with bells on the large end and sometimes on the small end. The radii of bends can rarely be ascertained in advance.

"Even when drawings are furnished, unless an inspector is at the works, the castings are quite as likely to come of some other pattern and weight (not usually lighter), when the alternatives are to use those sent or wait for others to be cast and delivered.

"On the other hand, it is clearly impossible for the manufacturer to keep a stock of pipe or specials on hand, when he cannot be sure that any two orders will have the same requirements, even in the simplest detail.

"The entire lack of system in fixing the weights of pipes is the cause of much trouble and perplexity, the weight cards of the different foundries agreeing no better than the tables of different engineers. The great variety in specifications not only causes trouble in the foundry, but results to the purchaser of pipe not inspected at the works and of pipe in small lots or on quick orders, in the receipt of pipe which, although it may make fairly good work when laid, is nothing more nor less than a job lot of different sorts and sizes, very difficult to lay."

Now let us consider the circumstances which inspired this portion of and intent of the committee and report.

Just as stated, the weight cards of the foundries varied as much as the engineers' tables, and often the results obtained by the foundries themselves varied considerably from their own weight cards; and for a number of years the cry of the foundries was that the engineer's ideas as to the dimensions of the pipe for a given service and the forms, not only of his specials, but of the bells and spigots of his pipe, varied so from that of his brother engineer that the foundryman didn't know how to provide patterns, etc., to meet the demand; in other words, he didn't know "where he was at." This was, to a large extent, true, and and it is indeed gratifying to pipe purchasers generally, and must be quite satisfying to your committee, to note how generally the engineers have been willing to either wholly or in part drop their individual ideas and standards and adapt themselves to the New England Specifications.

Observations of the extent to which the various classes of pipe have been used by those taking the New England Specifications as their standard, indicate that —

On 4-in., 6-in., and 8-in., classes E and G have been most used;
10-in., 12-in., and 16-in., classes D, E, and F have been most used;
20-in. and 24-in., classes C, D, and E have been most used;
30-in. and 36-in., classes C, D, E, and F have been most used;
48-in. and 60-in., classes C, D, and E have been most used;

with a tendency toward heavier pipe — this tendency being due to the higher pressures demanded and to the increase in street traffic, both in bulk and, naturally, in weight. Where the lighter classes of pipe have been employed it has been mostly for connections in existing work, and on account of the advances in cost of pipe, where it has been necessary to get the greatest length of pipe for the least money, within reasonable safety for the use intended.

The enormous demand for cast-iron pipe, as well as other materials, during the last few years, and the consequent inability of the purchaser to get deliveries unless he were willing to take such pipe, both in dimensions and in quality, as the manufacturer would furnish, makes it difficult to arrive at a very close estimate of the proportionate quantities of pipe bought under the New England Water Works Association specifications, and under other or no specifications, but to speak roughly I estimate that about 33 per cent. of the cities of 30 000 and over in the New England and Middle Atlantic states are endeavoring to use the New England Water Works specifications; about 13 per cent. still use their own specifications; the balance I am uncertain about, but the difficulty of getting pipe during the last few years has had a somewhat deterrent effect, and probably many who would have liked to use the New England Specifications, have had to take what they could get or go without. Outside of the territory mentioned, not more than probably 15 per cent. are using New England Specifications, several still using their own, the balance accepting whatever they can get.

However, consulting and constructing engineers who have extended existing works or put in new have, almost to a man, used New England Specifications so far as the New England States are concerned. Outside New England comparatively few have used them, although some have.

The Committee on Standard Specifications of this Association has been revived for the purpose, as I understand it, of conferring

with the committee of the American Water Works Association, and also, if found advisable, of recommending changes in the New England Specifications when experience with their use shows that a change is needed. To me it seems appropriate that we ask ourselves the question; Has not the time about arrived when we should consider the advisability of some changes in the specifications?

Experience has shown that only about four classes, and they the middle classes, have been very generally used.

While to maintain one outside diameter and vary the weights or classes by increasing or decreasing the internal diameter would theoretically be a thing that would suit nearly all parties interested, both purchaser and manufacturer, it cannot be done successfully in actual foundry practice; for while a mechanism can be laid out on paper that would do the trick to a nicety, a mechanism to vary the cores for the different classes involves the making of a machine of various and very accurate adjustments, and as the average coremaker is not an expert machinist, he would not realize the importance of having the adjustments and cores just so, while the very nature of the material used in coremaking would militate against close adjustments on such a machine; or else it involves the making of a different core board for each of the variations of a given nominal diameter and, in turn, the making of various fixtures to take the different sized cores; all of which is not only expensive to get up, but also hard to keep track of and not get them mixed, which in turn would necessitate an additional force of fixture men, and therefore an increased cost of production, and consequent increase of cost to the purchaser.

While the New England Specifications do not confine themselves to one outside diameter for all classes, they do give several classes to each specified outside diameter, which calls for the increasing or decreasing of the internal diameter; and therefore the same difficulty in manufacture is experienced as there would be in trying to use only one outside diameter.

Now, as noted earlier in this article, there have been certain classes that have been quite generally used by those purchasing under New England Specifications; would it not be possible to eliminate a number of the classes of the various sizes and so

readjust those left that the requirements for foundry fixtures will be simplified, and the manufacturer can obtain the desired weights and thicknesses with such fixtures as have been found practical?

By this I mean that by having fewer classes, and so arranging their variations that, say, four sets of cores and allied fixtures could be gotten out by the foundries to cover the pipe that would ordinarily be used, a basis would be reached that would probably be satisfactory to all. Generally speaking, the foundries have fixtures on hand that could be readily adjusted to two outside diameters, though if a reduction in number of classes was made, the specified outside diameters might need some rearranging to meet the services they would cover.

One thing the specifications are silent on is, in that portion relating to hydrostatic test, about the length of time the pressure shall remain on the pipe. Experience has shown quite conclusively that with the ordinary method of testing and the length of time which the pressure remains on, the test does not develop defects in the walls of the pipe unless they are such that the pipe bursts; for the present method is to throw the hydraulic pressure on quickly and off quickly, and the only function it performs is that of water hammer. On the smaller sizes, and the light classes of the larger sizes where the thickness of the wall is such that defects cannot hide themselves so well, this, while not desirable, in a manner answers; but on the larger sizes of the medium and heavier classes it often takes from three to five, and even ten minutes, to allow the water to force its way through any porous places, and unless there is an inspector on hand to see that the pressure is maintained for a proper length of time, it is not always done, as the facilities of the testing departments of the foundries have not been arranged to keep pace with the largely increased output. For example, there is a foundry which is turning out about 500 lengths of 4-inch to 6-inch pipe per day, with only one piece of testing apparatus to take care of this output. Their working day is about nine and one-half hours, so that it doesn't take much figuring to see that there cannot be much time spent on testing each pipe if the entire lot is to be hydraulically tested.

Therefore, it would seem as though some requirement should be inserted that the hydraulic pressure be maintained on pipe of 4-inch to 14-inch diameter say two minutes, 16-inch to 24-inch say three minutes, 30-inch to 42-inch say five minutes, and 48 inch and over ten minutes, or such time as your committee may think best.

Another matter not covered by pipe specifications, generally, is the hydrostatic testing of special castings. It has not been required largely because of the variations in forms and dimensions, but it would seem to me fully as important as the testing of straight pipe, and would develop not only weaknesses in the way of defects of the iron, but possible defects in design; and apparatus can be arranged for making these tests.

The subject is a broad one and admits of many arguments and requires careful thought. It could be extended much further, going into details of the actual use of pipe, etc., but that is out of my line and should be covered by those who are using the pipe.

DISCUSSION.

PRESIDENT WHITNEY. The paper is now open for discussion. I think we should like to hear from Mr. McInnes, of Boston, who had great experience with pipes and castings.

MR. FRANK A. MCINNES.* I should like to ask Mr. Conard one question, and that is whether he thinks there could not be to advantage a change in our present test requirement for the strength of iron, which is that a bar 2 feet long, 2 inches wide, and 1 inch thick shall sustain a load of 1 900 pounds and shall show a deflection of not less than .3 of an inch. I recall cases where the deflection at 1 900 pounds would be about .25 or .26, and yet that iron would break up to perhaps 2 600 pounds with a total deflection of .35, entirely too hard to satisfactorily admit of drilling and cutting. It has always seemed to me it would be better to say that at 1 900 pounds the deflection shall be not less than a certain amount; in other words, is it practicable to limit the deflection at a certain loading without serious injustice to the foundry, and in that way eliminate the possibility of getting very hard iron?

* Assistant City Engineer, Boston, Mass.

Mr. Conard. I should say, yes. On a number of tests that were made some years ago for the Metropolitan Water and Sewerage Board, a series extending over a matter of possibly ten months or a year, my recollection of the deflections is that at 1 900 pounds the deflection was about .24, .25, or .26 inch, with a further deflection at 2 100 pounds of about 4 or 5 points further, and the deflection advanced with the strength of the iron in just about that ratio, about .05 of an inch for every 200 pounds of pressure brought to bear on the bar from 1 700 pounds up. Below that I have taken no records.

The President. I wonder if Mr. Foss could give us any points in regard to the tests of metal referred to by Mr. Conard?

Mr. William E. Foss.* I am not familiar with the results of those tests, so cannot state intelligently anything about them.

The President. How much experience have you had with these standard pipe specifications, Mr. Foss?

Mr. Foss. Very little. Most of our pipe laying was completed before the standard specifications were adopted, but during several years on this work I had considerable experience in laying pipes cast under the Metropolitan Water Works specifications then in force. There are two points that I had thought of on which I should like to hear from Mr. Conard. He has already mentioned one of them, that is the testing of special castings. It always seemed to me that it was much more important to test the special castings than it was to test the straight pipes, but I had not understood before just why the specials were not tested. The other point I should like to ask about is in regard to the special curves for 48-inch and 60-inch pipe lines. I have found in laying pipe lines with these curves of large diameter that the curves throw an angle less than is specified. It is always that way; the deflection obtained is less than the specified angle of the curve used. I suppose there is a reason for it, and perhaps Mr. Conard can tell us what it is.

Mr. Conard. I don't know as I quite understand just what you mean. You mean there is a difference that does not show in the design of the special between the short side and the long side of the curve?

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* Division Engineer, Metropolitan Water Works, Boston, Mass.

Mr. Foss. Yes. For instance, a 45-degree curve, instead of throwing 45 degrees, will throw about 44 or 44½ degrees; and a $\frac{1}{16}$ curve will throw 22 degrees or perhaps as low as 21 degrees, or even less, instead of the specified 22 degrees 30 minutes.

Mr. Conard. Don't you find it works the other way too, at times?

Mr. Foss. No. All my experience has been that the special throws less than the specified angle.

Mr. Conard. My experience with specials is that the length will vary somewhat. Testing them with a templet I find variations; some of them come short, some of them come longer than called for, and the only solution I could ever get of it is that it is due to shrinkage, that there will be variations in the shrinkage of the iron. I have also found that where a casting was carefully built up, the mold built just to length, making allowance for this shrinkage, on the short side it might come less than the requirement and on the long side be long, therefore throwing the angle out somewhat. Then I have found it where both sides would be long, and I have also found it where the shortest side was a bit long and the long side a little short. The only reason I could ever give for that was the shrinkage was not always quite equal in the cooling of the casting. If you will just remind me what your first question was, I should like to answer that.

Mr. Foss. That one regarding testing of specials; I think you did answer in a measure in your paper.

Mr. Conard. It would seem very important that specials should be tested. One reason why it has not been done is because of the difficulty of getting up apparatus which would do the work satisfactorily at the foundry. That, I guess, is the real reason why it has not been done heretofore. But it would seem to be a good thing, and a very important thing. I have in mind a 48- by 36-inch tee, which I was looking at some years ago, which was defective, as I claimed. The foundry took exception to the matter and it was carried along for some time. Finally the casting was shipped to the point of destination and I was afterward called over, before the casting was used, and after a conference the casting was broken and it was very clearly demonstrated that the

casting was not only defective, but very defective. If an arrangement could have been made to have subjected that casting to a pressure test at the foundry it would have very clearly demonstrated there and then that it was a defective casting, and it would have saved a lot of worry and trouble.

MR. FOSS. There is one other point which possibly Mr. Conard can give us some information on, and that is the coating of pipes on the outside. I don't know what the foundry practice is, but I imagine from what I have seen of pipes that have been exposed to gases and electrolysis that after the pipe is coated it must be rolled out on skids while still damp, before the coating has thoroughly hardened; as I find that rusting and disintegration of the iron take place in rings about 2½ feet from the bell and spigot ends. It would be very desirable to have that avoided.

MR. CONARD. That is another case where the foundries have not quite kept up with their output in handling the pipes for coating. The output at the present time of the pipe foundries is such that it would simply be impossible for them to take a pipe and coat it and lay it in a position where it might remain inert until the coating had hardened so that there would be no breaking of the surface after it was cooled. It is true that as a rule they are placed on skids and turned over, or partially turned over every few minutes until they reach the point of weighing and testing. That is done for two reasons. One reason is to allow the flow of the coating to become equal all over the pipe, as the pipe and coating are both hot when the pipes are dipped, and naturally the coating stays somewhat fluid until cool; and the other, of course, is to make room for pipe which are being coated afterwards.

MR. JOHN DOYLE.* I think I can agree with what the gentleman on my left [Mr. Foss] says with regard to the variation of specials. My experience has been in laying 40-inch pipe and 30-inch pipe on a 50-foot radius, the trench having been laid out by a competent engineer, that I could not make both ends meet, and it has been necessary for me to make the trench fit the pipe. I have found quite a difference between the long end and the short end of the curved pieces, and I have found that in a great many instances.

* Boston Water Works, Boston, Mass.

MR. FRANK L. FULLER.* I think this testing of special castings is a very important matter, and am glad it has been brought up. In a water works job this last season, with 7 or 8 miles of pipe, there were at least 4 specials that proved defective. I don't know how many others there were, because, in many cases, we had to do the back-filling before the pipes were tested. In one case, where it was necessary to cross a river on a special bridge, two out of four ⅛ bends, which had come late in the season and which we needed at once, were defective, and we were obliged to wait three or four weeks to get new ones; and one of these was defective. We calked it up the best we could and let it go. I suggested to the foundry that it would be a good thing to test their specials, but they said they made so many they could not do it. It seemed to me that the more they made the more necessity there was of testing them.

Now it is very annoying to get a line of pipe laid and turn on the water and find that some of the specials leak. It means a long delay in getting new ones. If you have a leaky straight pipe you generally have pipe enough on hand to replace it and you get over your difficulty at once; but if you have a leaky special and have to wait three or four weeks to get a new one, it is a serious affair. I think the towns and cities would be willing to pay enough more for their specials to have them tested, and I think it would be a great satisfaction to know that the castings we are using had actually been tested and were perfect.

MR. CONARD. The question has been asked, Why cannot the hydraulic test be made on specials handily by using a ball or knuckle joint on the angle end of a special? There could be apparatus arranged for testing specials, but it would be quite expensive, though I saw a wrinkle only a few weeks ago at the Pennsylvania Steel Casting Company's works at Chester, Pa., which appealed to me quite strongly for the testing of special castings. The folks there had arranged a large circular frame with four moving heads operated by hydraulic power, and by that method they were able to clasp almost anything, of almost any shape, and subject it to hydraulic pressure. It seemed to me if this question of testing specials were only taken up and

* Civil Engineer, Boston, Mass.

insisted on (made a portion of the specifications), the manufacturer would be willing to put in some such apparatus, and I think that an apparatus of that character could be made to work quite satisfactorily.

THE PRESIDENT. I think we should hear something from the foundrymen's end of this subject, and I will call on Mr. Walter Wood for a few remarks.

MR. WALTER WOOD.* It was exceedingly interesting to me to hear the opening suggestions of the paper about what we used to run up against in the olden times. Every engineer used to send in a different pattern, not only for the internal diameter of his pipe, but also patterns for an infinite variety of special castings. I am glad that this old history has been touched on, because it is a source of great annoyance as the pipes are being laid, and it is often and naturally thrown up at the manufacturer that he was making things of every kind, when as matter of fact he was compelled to do so on account of the variety of orders which came in and to which he had to adapt himself.

It is fortunate, however, that the discussion about standards has gone so far that a large part of that irregularity has been eliminated from the burdens that have been thrown upon the foundryman. He is only too ready to adjust himself to any lines that can be worked on regularly, and it will be a comfort to him, and a great comfort to the people in the pipe trench, if steps in that direction are well taken, and they will always have the foundryman's strong and active support. It will take a little while to thresh the matter out. Our pattern loft is filled with all sorts of designs, and some people will still have specials or goods made from those designs. But time will settle all that, and when we get the subject of standard specifications finally worked out the trouble will be a thing of history.

There is one thing that I am sorry occurred about forty years ago. It is well known in New England in connection with the Salem water works. Perhaps none of us are quite old enough to recollect all the occurrence, but it has gone into history, and we are more or less familiar with it.

I refer to it merely to lead up to this one fact, that so far as I

* Of R. D. Wood & Co., Philadelphia, Pa.

have any knowledge of cast-iron pipe foundries, there is absolutely no attempt on their part to do otherwise than to follow the wishes of their customers. I think they all wish to do thoroughly good work, and all wish to fall in with ideas that are put before them, although sometimes making practical suggestions regarding them; but there is no thought on the part of any of the founders whom I know of any antagonism or difference of interest — that is the best word to use — between the persons who buy and the persons who make. Our interests are all one, and I think anything which is taken hold of by the users of pipe which will benefit the manufacture and the furnishing of it, will be met with that spirit on the part of the manufacturers.

The specifications which were originally adopted by the New England Water Works Association, and which were so widely spread and so widely used, have naturally come under more or less discussion, and particularly on one point, which was alluded to in the paper just read and I think very properly so; that is, the large number of classes in the specifications. The discussion which has taken place on the subject of classes has largely brought itself down to this: If you will take the two extremes of weight which are generally used in pipes, you will find that about four classes will cover this range of weights, so that each class will not be more than the allowed variation from the other. Of course I am speaking approximately. In other words, there is an allowance of 8 per cent., four up and four down, and there are four classes, and that is 32 per cent. That will largely cover all the variation of weights between the high weights and the low weights, and, therefore, a more careful investigation of the subject of classes has led those who have followed the New England movement to come to four classes.

The gentleman who read the paper very properly alluded to the question of the making of cores, and whether the variation of weights could be made through the variation of the cores or through the variation of outside diameters. If that question is carefully looked into with the drawings before you, you will find that four classes can be reached with the use of two patterns of outside diameter, and one variation of the core for each; this will make the four classes. You will, therefore, only have one variation

of outside diameter and one variation of core, which will simplify the question very much with the manufacturers; and while it is not exactly the best theoretical way of meeting the question, yet it is probably the best solution between practice and theory. In this way the matter of classification readily adjusts itself.

There was a suggestion in the paper that the manufacturers had a specification of their own. Perhaps in ordinary parlance there is some basis for alluding to it in that way. But, to put it a little more accurately, it is this way: The American Society for Testing Materials appointed a committee which, in considering the specifications, worked out the four classes I have alluded to, and also made some other changes, not very prominent ones, in the New England specifications. That society's specifications have now been before the country for some little time, and perhaps have been more used by the foundrymen in their own practice than the New England specifications, and hence they may have come to be called the foundrymen's specifications. But they are *not* the foundrymen's specifications; the fact is merely that when two specifications are laid before the foundryman he naturally chooses that which is the simplest, easiest, and cheapest to manufacture under. There is really very little difference between the two, and it is chiefly in the subject of classification which we have been speaking about.

It would be very well if specifications could be uniform not only in this country, but, for those of us who are on the seaboard, in foreign countries also. It is a matter of some pride with us in America to have foreign trade, and uniform specifications would very largely help. So perhaps that has been a factor in the foundryman's thoughts in working under the Society for Testing Materials' specifications, viz., the idea of working towards an international standard.

I only speak of this question of the foundrymen's specifications because I want to get it clearly before our friend's mind that there is no antagonism to the specifications adopted by the New England engineers.

There is one other thing in connection with international specifications which will naturally come up, and it is a very excellent one for the buyer to think seriously about. It is im-

possible to make a casting 13½ feet long without the upper end being more or less porous. Abroad their custom is to cut off that end for 3 or 4 or 5 inches, and in that way they get a much more perfect pipe than is called for by our American specifications. In our large-diameter pipes we have in our foundry adopted the principle very largely, though not in every case, of cutting off the ends of the pipe so as to secure a clean spigot. As it is an added expense, we haven't done it in every case, but the tendency of our manufacture is towards cutting off the upper end of every pipe in order to get a perfect spigot, which is a very desirable thing, because the bead is the weakest part of the pipe, and it is a constant trouble to the inspectors to know whether they should pass a pipe with 1 hole or 3 holes or a dozen holes in the spigot, and it is a constant source of worry and loss to the consumer and to the manufacturer until the point is settled. Had we better not adopt in this country the principle of cutting off that portion of the pipe which is always more or less porous and always giving trouble to everybody and is a source of constant friction? I suppose if we ever reach an international specification that will be one clause which every foreign engineer will insist shall be inserted, viz., to make a pipe perfect by cutting off the part of the pipe which is always more or less bad. Whether or not the time has come for doing that in this country is for the persons who buy pipe to settle. It will not add very much to the expense, and will certainly give them what we all aim for, that is, more perfect castings.

There is another matter which I may speak of as a matter of curiosity, although I think both the English engineers and the American engineers will be slow to adopt it. The best foreign practice is to have no bead on the end of the pipe. I think there is too much conservatism among our engineers, however, to do away with the bead offhand, and I only speak of it as an advance in the manufacture of pipe which has been largely adopted abroad, but which I am afraid our conservatism will keep us from promptly adopting here.

The function of the bead after all is not to strengthen the end of the pipe, because the slight ring of cast iron which constitutes the bead is too small a piece of metal to strengthen materially the end of the pipe. A 6-inch pipe weighs over 300 pounds, and a

12-inch pipe weighs 1 000 pounds, and no little ring of iron like a bead will furnish strength to stand the dropping of the pipe on its end. The bead adds so little strength to the end of the pipe that I don't know why it was put there originally, unless it was for the sake of helping to center the pipe as it goes in the socket, so the man in calking won't have the barrel of the pipe lying on the bottom of the socket. That is to my mind the real function of the bead, — that it tends to help the calking.

Now the way that is secured in the pipe that has no bead is to have a slight taper at the bottom of the socket, so that when the pipe is driven home the end of the pipe centers itself on the taper, and the full calking room is at once obtained, instead of the calking room which the bead gives, which is only the height of the bead and which is not the full calking room. So really a beadless pipe centers rather more accurately and rather more thoroughly than a pipe with a bead.

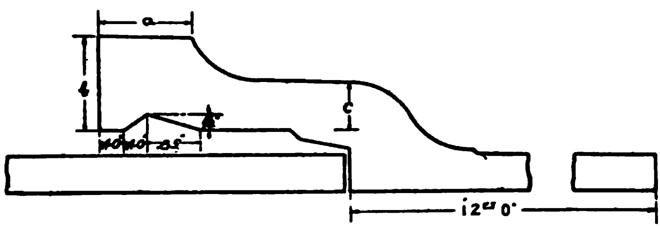


FIG. 1. JOINT IN CAST-IRON PIPE WITHOUT BEAD ON SPIGOT END.

The question of time in testing is an exceedingly interesting one. Perhaps I can illustrate it by speaking of the discussion which occurred in the American Society for Testing Materials as regards test-bars. The committee having that detail in charge brought the question before the Society, and one of the professors of a technical institution of Boston spoke on the question of the time of the test-bars in the test as influencing the ultimate breaking strength. Later he made some tests at our factory, and the result was that the element of time in testing test-bars was eliminated from the report. The time of the test has a certain influence, but not such a commanding influence as to make it a question to dwell on or an important point.

A pipe in a foundry is generally from one to two minutes in going through the press. As I have stood at the testing press where we test our 4- and 6-inch pipe, it is about a minute from the time it goes in to the time it comes out. The pressure has been on it even less than a whole minute, because part of the minute is taken up in the handling. In the case of larger pipe, of course the time has to be longer on account of the physical requirements in handling the machinery and the castings. We had one large contract for 60-inch pipe where the specification required that the test be kept on ten minutes, which, so far as I have learned from our foundry superintendents, developed nothing of value in the time of testing. Yet it is a question which I do not want to be settled offhand, and I should be glad to have you look into it, because anything which advances the manufacture is a thing to be adopted. I am only speaking of it as what we have learned from experience, that a long time in testing does not develop more strains than a short time in testing.

The allusion that has been made to the variation of angle of bends varying between 43, 44, and 45 degrees is one which I think was fairly explained; that is, the contraction of iron from a molten to a solid state is an uncertain question. The length of a straight pipe will vary from $\frac{1}{2}$ to $\frac{3}{4}$ inch simply from the contraction. That same thing happens in your curves, and on one side it will sometimes happen to be more than on the other. It is a thing which cannot well be avoided in manufacture. But unless the difference of curvature amounts to more than 4 or 5 degrees it becomes an insignificant quantity, because 4 or 5 degrees can be easily taken up in the adjustment of the spigots in the sockets.

The rings which Mr. Foss spoke about as being on the pipes after they are coated are something which is very annoying to the manufacturer. He doesn't like it, but what is he to do with a pipe after it comes out of the bath? He can't hold every pipe upon chains until it drains; he has got to lay them down. It would be unwise for buyers of pipe to ask for machinery to be made for suspending all pipe until cool, because it would add so much to the cost of the pipe that the game would not be worth the candle. Pipe has to be laid down and it has to be rolled to get it out of the way, and hence there will be rings.

I don't see how they can be avoided unless buyers of pipe wish to pay for placing the pipe on end, standing them around under cranes until they are cooled. Of course anything that the buyers of pipe want, the manufacturers will be ready to furnish and to accede to if it is understood in advance. The expense will be simply a question of so much per ton. But I really don't see any practical way of overcoming that matter of rings on the pipe. The pipe has to be laid down and rolled out of the way, unless there is some very elaborate arrangement for standing them on end.

The more important question, however, is the testing of specials. It is a very unsatisfactory thing on both sides. The question of testing pipe is a very simple thing, because after all a pipe is only a column, and to close one end you use a movable head and gasket which forces the pipe up against a stationary head with its gasket. The pipe is then subjected to a direct transmission of strains which cast-iron pipe is very well able to stand. Now when you undertake to test a cross or a tee you not only have to close the ends, but you have to close the arms. In closing those arms, especially in a large casting, sufficiently tightly to stand the pressure, you put new strains upon your castings, and strains which never occur in practice. So that, if castings are to be tested, it will involve a redesigning and using quite a quantity of extra metal. Now I am not giving this as an argument against testing specials, because, as I have said before, anything that the users of pipe want and will pay for they should have. But one of the things in connection with testing specials that must be borne in mind is that they will not only have to be tested for their work in the ground, but they will have to be designed to stand the unusual strain which the testing itself throws upon them.

I take it the reason that there has been no more trouble from the non-testing of specials than has been the case is because there is an extra amount of metal in the special, not for the sake of the foundryman getting an extra price, but because the cutting of a hole in the side of the pipe requires the replacement of an equal and more than equal amount of metal around the hole so that the casting will not break. To illustrate what I mean, we had a request at one time to test a lot of manhole branches. The long diameter of the manhole was parallel with the barrel of the pipe,

and we broke them right straight along. I suggested, Why not make the long diameter of manhole at right angles to the axis of the pipe? And instead of cutting a hole 18 inches in the side of the pipe, it was only 12 inches, and the casting stood. I only speak of that to show how you have got to replace the metal which you cut out of the side of the pipe for the opening, and more than replace it, because you don't put it where the strain really comes, but you put it at the side of the opening.

Now the question of testing, when it is practically and carefully worked out, comes down to the cost of testing and the cost of the additional metal which you put into the casting for safety. I should say it would be cheaper, speaking offhand, to furnish extra metal than to pay the expense of testing a special. If the buyers want them tested we will test them, but those two points had best be thought of, whether the cost of testing had not better be put into an extra weight of iron, and also the question of redesigning specials to stand the test strains.

Mr. Conard. Mr. President, in speaking of the pipe manufacturers having adopted a standard other than the New England specifications, I did not wish it to be inferred at all that I thought there was any antagonism on the part of the manufacturer as between what he thought should be the specifications and the specifications which had been adopted by the New England Water Works Association. I merely spoke of it to illustrate the fact, just as Mr. Wood said, that it was getting down to the basis of the best thing between theory and actual practice.

A little further on the question of the variation of the internal and external diameters: In making pipe designs you get a center for your core, and if the requirements as to variation of diameters between the largest and smallest diameter for a given nominal diameter are too great it will necessitate the making of a considerable quantity of additional fixtures, — socket irons, cups, centers, etc., and if the variation was very large possibly new core bars in order to take care of the amount of stock, as it is called in the foundry, which would work well. All of that would entail the making of a great many and various fixtures in order to make pipe of a given nominal diameter; and that is one of the reasons why, if the purchaser of pipe can reach the point where he feels

that he can possibly reduce the number of classes which he wishes to use, it will reduce the quantity of fixtures that would be necessary to get up for producing a given quantity of pipe, and that would tend to keep the cost of pipe within what the purchaser considers reasonable limits.

Mr. Foss. Mr. President, I should like to say a few words about curves being not as they are designed. That is a point I referred to, because the variation is always in one direction,— the deflection angle is always small. I measured fifteen or twenty 48-inch curves carefully after I had some trouble with them, and found the deflection angles were all smaller than specified. It becomes a matter of considerable importance on large pipe. On small pipe, 6, 8, 10, or 12 inches, it doesn't matter, but with a 48-inch or 60-inch pipe it does. The most you can deflect a 48-inch pipe by opening the joint is about one degree in good practice. If you have a corner where you want to use four $\frac{1}{16}$ curves to make a quarter turn, and each of them is out about 2 or $2\frac{1}{2}$ degrees, you need another special to make the turn, because you cannot do it by opening the joints. As the deflection angle is always too small, it seems to me some allowance might be made so that the curves will average about what they are designed for, if the error is due to shrinkage.

In regard to the bead on the pipe, I think there is a point in connection with the practical use of it which has been overlooked. I do not think it is of value so much for strength as for use in laying. It is a stop for the yarn, and is of use in raising the pipe when spacing it evenly in the socket. The method suggested of having a tapering socket to center the pipe in would not amount to very much in practice, because there is not one time in fifty that a pipe line is exactly straight. You are either laying it around a curve or over a hill, or something of that kind, so that you are deflecting from a straight line or grade all the time, and the spigots would not be centered in the sockets.

Mr. Wood. Mr. President, if it is a fact about the curve straightening itself out under contraction, — which I would be very glad to look into, because it is an interesting thing and something I never have had called to my attention, — it is a simple matter for the engineers to instruct their inspectors to have a

larger angle provided in the mold, so that the pipe will be eventually, when cooled, exactly the angle wanted. But in saying that I want to leave this thought, that the amount of contraction in cooling is a thing which I am afraid Nature takes care of very much more than mankind, and we will never be able to absolutely control it. We see that constantly in making flanged pipe, where we are expected to make them to an exact finished length and we never can do it without facing off the back of the flange and making the flange materially thicker in order to give metal to take the come and go of the contraction.

As to the matter of the bead, I think I made it clear that the conservatism in this country and in England will hardly permit its being taken off. As to its working in actual practice, there is no question whatsoever. It is discarded on so many thousand tons of pipe that its working in actual practice is a settled question, and it is settled to such an extent as this, if you will pardon me for a moment in explaining. We took quite a large contract for Java. The Dutch government felt uncertain as to the ability of Americans to make cast-iron pipe, and they sent their engineers over here to see whether it was possible for us to do it. I at once objected to their having no bead on their pipe. The engineers said they would put on their hats and go home, that they knew enough about the subject to know what they were talking about, and that this pipe was to have no bead or there was to be no contract. That is the way the people look at it who have worked it out in practice. You can make a good many objections to almost anything that is new, and yet in practice it has worked and does work satisfactorily.

PROCEEDINGS.

December Meeting.

Hotel Brunswick,
Boston, December 12, 1906.

William T. Sedgwick, President, in the chair.
The following members and guests were present:

Honorary Member.

Wm. T. Sedgwick. — 1.

Members.

C. H. Baldwin, L. M. Bancroft, F. A. Barbour, W. T. Barnes, J. W. Blackmer, George Bowers, G. A. P. Bucknam, F. H. Carter, J. C. Chase, J. W. Crawford, A. W. Cuddeback, A. W. Dean, H. P. Eddy, F. F. Forbes, W. E. Foss, F. L. Fuller, J. A. Gould, F. E. Hall, J. O. Hall, L. M. Hastings, T. G. Hazard, Jr., D. A. Heffernan, H. G. Holden, J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, L. P. Kinnicutt, C. F. Knowlton, E. S. Larned, Thomas McKenzie, H. V. Macksey, N. A. McMillen, D. A. Makepeace, A. D. Marble, W. P. Mason, F. E. Merrill, Leonard Metcalf, F. L. Northrop, O. E. Parks, E. M. Peck, G. H. Palmer, E. B. Phelps, T. A. Peirce, Ransome Rowe, W. W. Robertson, H. W. Sanderson, E. M. Shedd, C. W. Sherman, G. H. Snell, W. F. Sullivan, R. J. Thomas, W. H. Thomas, L. D. Thorpe, D. N. Tower, W. H. Vaughn, F. B. Wilkins, G. E. Winslow. — 59.

Associates.

Builders Iron Foundry, by A. B. Coulters and F. N. Connet; Chapman Valve Manufacturing Company, by Edw. F. Hughes; Hersey Manufacturing Company, by Albert S. Glover, H. V. Macksey, and W. A. Hersey; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. L. Northrop and C. E. Merrill; R. D. Wood & Co., by W. F. Woodburn; Water Works Equipment Company, by W. H. Van Winkle. — 20.

GUESTS.

E. L. Field, chairman Water Board, Northfield, Vt.; J. H. Hill, commissioner, Lowell, Mass.; H. E. Cowan, I. N. Scribner, L. Vredenburgh, Boston, Mass.; A. E. Blackmer, superintendent Water Works, Plymouth, Mass.; C. W. Gilbert, Woburn, Mass.; C. H. Pierce, Springvale, Mass.; F. A. Collins, Philadelphia, Pa. — 9.

[Names counted twice. — 5.]

The Secretary read the following names of applicants for active membership, all of whom had been approved and recommended by the Executive Committee:

Non-Resident. — John Herbert McManus, West Hurley, N. Y., assistant engineer, Water Department, New York City; Perkins Boynton, Little Falls, N. J., bacteriologist and chemist, East Jersey Water Company, Little Falls, N. J.; Burton G. Philbrick, Brooklyn, N. Y., water sanitarian, Lederle Laboratories, New York; August E. Hansen, New York City, sanitary engineer with Williams, Proctor & Potts, New York City; Selskar M. Gunn, Iowa City, Iowa, assistant bacteriologist, State Board of Health, Iowa; Luther R. Sawin, Mt. Kisco, N. Y., chemist and bacteriologist, New York Water Department; Louis J. Richards, Elizabeth, N. J., health officer, Board of Health, Elizabeth, N. J.; W. F. Currier, Philadelphia, Pa., chemist and bacteriologist with Booth, Garrett & Blair, Philadelphia, Pa.; William J. Roberts, Pullman, Wash., professor of civil engineering, State Agricultural College, and consulting engineer, State Board of Health of Washington; Henry A. Pressey, Washington, D. C., designer and constructor of water works and sewerage systems; Arthur B. Cleaveland, Orman, S. D., United States Reclamation Service; E. F. Kitson, Norfolk, Va., supervising engineer for Southern Construction Company, etc.; John W. Maxcy, Houston, Tex., designer and constructor of water works and purification of public water supplies; Alex. J. Taylor, Wilmington, Del., engineer Sewer Department, Wilmington, Del.; L. R. Thurlow, health officer, Plainfield, N. J.; Charles F. Breitzke, White Plains, N. J., with John M. Farley, civil engineer, and in charge of construction of reservoir at Mt. Kisco, N. Y.; William H. Beers, Jr., chemist and bacteriologist, Water Department, Columbia, N. C.

Resident. — Nathaniel W. Hayden, Windsor, Conn., president and manager Windsor Water Company; Albert L. Sawyer, Haverhill, Mass., registrar Haverhill Water Works; Jas. A. Newlands, Middletown, Conn., assistant chemist and bacteriologist, Connecticut State Board of Health; William L. Butcher, Boston, Mass., assistant in office of chief engineer, Massachusetts State Board of Health; Herbert C. Emerson, M.D., director Emerson

Laboratory and member of Board of Health, Springfield, Mass.; Frederick W. Farrell, Springfield, Mass., chemist and bacteriologist, Emerson Laboratory, Springfield, Mass.

On motion of Mr. Fuller the Secretary was requested to cast one ballot in favor of the gentlemen whose names had been read, and he having done so they were declared duly elected members of the Association.

PRESIDENT SEDGWICK. There is one matter which the Executive Committee has instructed me to bring before the meeting, and that is a vote of theirs, as follows:

"In view of the immense economic importance to the people of New England of the careful preservation of their forests, for the safeguarding of their water supplies and water powers, it is recommended that the following resolution be passed by the Association:

"That the President and Secretary be authorized and instructed to address an appeal on behalf of this Association to the members of the House of Representatives from New England urging each Representative to petition the Speaker without delay that the bill now pending, known as House Bill No. 13, which provides for the establishment of the Southern Appalachian and White Mountain forest reserves, be taken up for final action at an early day in the present session."

With reference to this action of your Executive Committee, I should like to say one word. The bill described here has been pending for some time in the National Congress. It has been passed by the Senate, it is strongly favored by the President, but we are told that it is being "held up" by the Speaker, who declines to allow it early consideration in the House. Those who are interested in this bill, and they are a very large number of the inhabitants of New England and of the eastern United States, — for this covers the Southern Appalachian as well as our own mountain region, — desire to get their members in Congress to bring it forward as quickly as possible. Moreover, while a resolution like this passed by the Association to-day will be of value, the most valuable thing which can be done, and the most helpful, will be for every one of us to write a letter to his Representative — not to his Senators, but to his Representative in

Congress — or to see him, personally, and urge him to advance so far as he can the interests of this bill.

This Association does not go into politics, but your Executive Committee does not think that this is politics. This is literally self-preservation. If the White Mountain region is to be denuded the damage to our New England water powers will be very great. Here is a bill, the passage of which is desired by a very large proportion of our people, and which we, as an association of water works men, feel deeply interested in. I would, therefore, respectfully urge you to get into touch, if you can, with your own Representatives from Massachusetts, Connecticut, Rhode Island, New Hampshire, Vermont, and Maine, and ask them to push this thing forward as fast as they can. The resolution is a formal one, and you can quote it to your Representative if you like. It comes before you with the recommendation of your Executive Committee that it be passed. What is your pleasure with regard to it?

On motion of John O. Hall it was unanimously voted that the resolution be accepted and adopted.

The first paper of the afternoon was by Mr. E. S. Larned, of Boston, Mass., and was entitled "Use and Tests of Cement and Concrete." Mr. Frank L. Fuller and Prof. William P. Mason took part in the discussion. The second paper was on "The Explosion of the Saratoga Septic Tank," by Dr. William P. Mason, professor of chemistry Rensselaer Polytechnic Institute, Troy, N. Y. This paper was discussed by Prof. L. P. Kinnicutt, Mr. Harrison P. Eddy, Mr. John A. Gould, Mr. Frank A. Barbour, Mr. Earle B. Phelps, and the President.

Adjourned.

Annual Meeting.

Hotel Brunswick,
Boston, January 9, 1907.

The President, Prof. William T. Sedgwick, in the chair.

The following members and guests were present:

Honorary Member.

Wm. T. Sedgwick. — 1.

MEMBERS.

S. A. Agnew, M. N. Baker, C. H. Baldwin, L. M. Bancroft, G. W. Batchelder, C. A. Bogardus, J. W. Blackmer, George Bowers, E. C. Brooks, G. A. P. Bucknam, James Burnie, C. E. Childs, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, A. O. Doane, J. N. Ferguson, A. D. Flinn, J. H. Flynn, G. H. Finneran, F. F. Forbes, W. E. Foss, A. D. Fuller, F. L. Fuller, W. B. Fuller, J. C. Gilbert, D. H. Gilderson, A. N. French, A. S. Glover, J. O. Hall, J. C. Hammond, Jr., V. C. Hastings, D. A. Heffernan, H. G. Holden, W. S. Johnson, E. W. Kent, Willard Kent, Patrick Kieran, G. A. King, C. F. Knowlton, S. H. McKenzie, Hugh McLean, N. A. McMillen, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, Leonard Metcalf, H. A. Miller, F. L. Northrop, E. M. Peck, Wm. Naylor, J. H. Perkins, E. M. Shedd, C. W. Sherman, Sidney Smith, G. H. Snell, G. A. Stacy, W. F. Sullivan, H. A. Symonds, J. A. Tilden, R. J. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, G. W. Travis, W. H. Vaughn, C. A. Townsend, C. K. Walker, J. C. Whitney, G. E. Wilde, F. B. Wilkins, G. E. Winslow. — 74.

ASSOCIATES.

Harold L. Bond & Co., by Harold L. Bond; Chapman Valve Manufacturing Company, by Edw. F. Hughes; Coffin Valve Company, by F. E. Adams; William H. Gallison Company, by H. E. Stilphen; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey, A. H. McAlpine; International Steam Pump Company, by Sam'l Harrison; Jenkins Bros., by J. D. Stiles; The Fairbanks Company, by F. A. Leavitt; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; National Meter Company, by C. H. Baldwin, J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Rensselaer Manufacturing Company, by C. L. Brown; Platt Iron Works Company, by F. H. Hayes; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. L. Northrop; United States Cast Iron Pipe & Foundry Company, by F. W. Nevins; R. D. Wood & Co., by W. F. Woodburn; Water Works Equipment Company, by W. H. Van Winkle. — 24.

GUESTS.

F. L. Weaver, A. Weaver, E. B. Carney, C. A. Nelson, Lowell, Mass.; E. T. Harvell, Rockland, Mass.; F. L. Clapp, superintendent Water Works, Stoughton, Mass.; Clifford Baylies, water registrar, New Bedford, Mass.; Edwin Leavitt, Somerville, Mass.; N. P. Potter, Braintree, Mass.; Samuel W. Hoyt, Jr., South Norwalk, Conn.; A. E. Blackmer, Plymouth, Mass.; George F. Whitney, Natick, Mass.; John J. Nugent, water commissioner, and Frank Woodbury, 2d, chairman Water Board, Beverly, Mass.; Frank Smith, Kineo, Me.; Charles H. Rollins, commissioner, Watertown, Mass.; H. E. Cowan, Boston, Mass. — 17.

[Names counted twice. — 5.]

After dinner had been served President Sedgwick called the meeting to order and spoke as follows:

President's Address.

Gentlemen of the Association, — A wise custom makes it incumbent upon the retiring officers of your Association to give at the annual meeting some account of their stewardship. In conformity with this custom I propose in a few words to call your attention to the principal events of the year that has gone, to touch upon the present and prospective condition of the Association, and then to make way for those who are nearer the field of action — the Secretary, the Editor, the Treasurer — than is your President.

Associations like ours date back, as you may be interested to know, for about three hundred years. Almost exactly three hundred years ago a little band of scientific students — we can hardly call them scientific men — in Rome, got together, in the absence of any prevailing popular scientific enthusiasm, in the absence of events of stirring scientific interest, such as surround us to-day, but yet filled with the love of knowledge, and with an enthusiasm for Nature and for the study of Nature, and formed a body which they called the Society of the Lynx, that is to say, of the keen-eyed. That society, which is known as the *Accademia dei Lincei,* was the first in a long series of scientific societies and technical organizations like our own from that day to this. It still exists in Italy and is the leading scientific organization of that now strong, active, and enterprising country. It was followed by the organization of the Royal Society of London, that by the French Academy of Paris, and that by a similar society in Germany; and from that day to this earnest and thoughtful and enthusiastic students of Nature and the Arts have gathered themselves together, as we have done in this Association, for mutual benefit and for the study of the things that interest us in this world.

The year that is gone has shown no great change in the characteristics of our Association. It still remains an organization for mutual benefit, and it still has the same objects in view which it has had from the beginning. Some of those I may touch upon in a moment. But first let me say that we are rapidly becoming

a body of more than local importance. Our numbers are drawing near the 700 line. They have increased this year from 645 in all to 684 in all. Our Associates have fallen in number from 53 to 51; our Honorary Members have increased from 8 to 15, and one of our Honorary Members, Mr. Croes, a justly famous engineer, has died. The decrease in our Associate membership is, doubtless, due in large measure to the tendency of the times to combine, and thus diminish the number of industrial and similar organizations. The growth in our active resident and non-resident membership seems to me strong testi mony to the usefulness of the Association for never before has there been a time when men have been invited to join so many organizations or pay so many fees as to-day. When, therefore, we find 600 men and more continuously connected with the New England Water Works Association and paying their fees with regularity and promptness we cannot help but feel that they get something out of the Association; in other words, that they find it useful.

Before leaving the subject of membership, upon which I do not care greatly to dwell, I do wish to say one word about our Honorary Members. It has seemed to me for some time, in fact ever since I was myself elected an Honorary Member, — thanks to your courtesy and consideration, — that our list of Honorary Members was not yet such as was worthy of the Association; I mean that it did not contain many of those distinguished names which might well be upon our rolls with honor to the Association and with honor to themselves. I was, therefore, very glad when the Executive Committee at the Annual Convention proposed, and when the Association elected, a number of the most distinguished men in the United States more or less closely connected with water works, to honorary membership in this Association. It became my pleasant duty to notify these gentlemen of their election, and I have here the letters which they wrote, accepting — as they all did — honorary membership in the Association and the honor and distinction conferred upon them by you.

I propose now, at the risk of taking a little time, to read extracts from these letters, because I take it to be a matter of marked and permanent interest to a body like this, when men of distinction, such as these whom we have elected and who have accepted

honorary membership, say some of the things which they have said in their letters.

I will read first the letter of acceptance from the eminent engineer, Mr. Joseph P. Davis. I will omit, as a rule, personal references and the address and signature:

"Your favor of the 6th inst., notifying me that I have been elected an Honorary Member by the New England Water Works Association, is at hand. I accept the election with great pleasure. Please give my sincere thanks to the Association for the honor conferred, an honor which I appreciate highly. Also please accept my thanks for the very kind terms in which you notify me of the election."

I may say that substantially the same letter was sent to all, to the effect that the Association had pleasure in conferring honorary membership upon the person addressed, in view of his distinguished services to water works science.

The next letter is from Mr. Edwin Reynolds, of Milwaukee, or rather from Mrs. Reynolds, because, I regret to say, of the illness of Mr. Reynolds. She says:

"Mr. Reynolds has been confined to his bed most of the time for the last nine months. He wishes me to say, in answer to your communication, that he highly appreciates the distinction of being an Honorary Member of your society and accepts the election with pleasure."

The next is from Mr. John T. Fanning, of Minneapolis, who says:

"I have received your letter announcing the honor conferred by the New England Water Works Association at its recent meeting in the White Mountains. I appreciate the kind words with which you have accompanied the announcement, and assure you that I appreciate such honoring remembrance of an absent member by the Association. I shall be pleased to accept the honorary membership which the Association courteously voted. I had hoped to be present at the September meeting, but was unfortunately called to an engagement in Canada just at that time."

The next is from Mr. E. D. Leavitt, of Cambridge:

"I accept with pleasure the election as an Honorary Member of the New England Water Works Association, a society whose

good work makes it *a public benefactor*. With thanks for the honor conferred, I remain,

"Sincerely yours."

The next comes from Mr. Rudolph Hering:

"I wish to convey to you my high appreciation of the honor which the Association has kindly conferred upon me, and to thank you for your kind expressions. Of course I could not do otherwise than accept the election, which brings so much honor with it, and I do so with the feeling that, while I hardly deserve what you say, my life may yet be useful in advancing the science of engineering in theory and practice, as it has always been my effort in a small way to do."

The next is from Dr. Henry P. Walcott, the distinguished chairman of the State Board of Health of Massachusetts, and a member of the Metropolitan Water and Sewerage Board of the same state:

"I have your kind note informing me of the action of the New England Water Works Association in electing me to an honorary membership in the Association. I accept the honor with great pleasure, for I have a high regard for the important work of the Association, and as a member of the State Board of Health have more than once been greatly indebted to it for advice and assistance."

From Mr. F. P. Stearns, formerly chief engineer of the State Board of Health of Massachusetts and later of the Metropolitan Water and Sewerage Board of Massachusetts:

"Your letter containing the information of my election as an Honorary Member of the New England Water Works Association was handed to me yesterday on the train as I was leaving Boston. Although I have not been able to attend many meetings of the Association in recent years, I have always highly appreciated the very good work which it has done, this result being due to the many able men enrolled in its membership and to their willingness to work and to contribute freely to the general fund of information on water works management and construction. Having such an opinion of the Association, I can and do appreciate most highly the honor conferred upon me by this election. Permit me in accepting membership in the Association to thank you, and through you the Association, for its action."

And finally from Mr. Hiram F. Mills, the eminent hydraulic engineer, who has been for so many years the devoted and self-sacrificing engineer-member of the State Board of Health of Massachusetts:

"Your very kind letter informing me of my election as an Honorary Member of the New England Water Works Association is received. It is about twenty years since at a meeting in Boston I told the members of the Association what the State Board of Health of Massachusetts proposed to do in order to improve the quality of water used in public water supplies, and asked their coöperation. In the meantime, the members within the state, almost to a man, have intelligently and cordially co-operated with the board in its efforts to render the water supplies more helpful, for which the board and their own communities have reason to thank them. The effort to improve, and the questions which the members of the Association have found it profitable to consider, have raised the standard of the men having charge of such work throughout the bounds of the Association, and I am happy to receive from such a body of men the expression of this honor."

Now, gentlemen, these well known and distinguished names stand to-day upon our roll as Honorary Members of this Association, and it seems to me they confer dignity upon and add luster to it. Let us be careful that as we go on in the future we add to our honorary membership only men of similar rank; and in adding to our active resident and non-resident and to our associate membership, let us also watch carefully over the quality and character of the men whom we invite to become members. At the same time let us not be exclusive. There are in particular a great many *young* men who ought to belong to this Association, so that they may get the benefit of contact with older men and of the papers which are read here, — the social side and the intellectual side. I think we have all been a little negligent in not bringing in more of the young men. Let us see if in the future we cannot add more of them to our active membership.

The object of this Association is, first and foremost, social intercourse. By that I mean the friction of mind on mind, the exchange of ideas, and especially of technical and professional

ideas, discovering whether we are up to date or behind the times by contact with our neighbors who may be more alert than we are in particular directions. We ought never to allow at our meetings and luncheons the formal papers to crowd out that part of our work. We ought, therefore, always to have the hour of meeting such that there shall be opportunities for social conference before or after our meetings, and generally, of course, before.

Most of us come here to get information, but we should remember that we ought to give information too. I have repeatedly urged upon the members the necessity of bringing here the results of the practical experience of every-day life, of work in the field, by noticing things that are interesting or suggestive and bringing them here and talking about them. If this Association degenerates so that our meetings become merely a place for the giving of lectures or for the reading of long disquisitions, it will never fulfill its principal function. *Discussion* is, and always will be, the essence of the successfulness of any such association as this, — the give and take, the quick answer which comes to the new idea thrown out by some one, — resisted, or accepted, or illustrated or improved upon. We need, therefore, to be careful, especially you gentlemen who are superintendents in actual service and familiar with practical details, to look out for the glib talkers — the professors and similar people — who can, perhaps, lecture to you by the hour but who, perhaps, after all, cannot help you half so much as your neighbor who may be far less fluent but far more expert in actual water works warfare. We need, therefore, to give careful attention to our *programs*. And we are not alone in this matter, for it is felt by many a society to-day that there is danger of being swamped by long papers which allow little or no time for discussion. We must have the vital discussion if we would remain successful.

In this connection a suggestion has been made by Mr. Baker that it is a pity that many of our papers are not submitted in print so that written discussions can be sent in. That is done, as you know, in many associations and societies, and it is well worth thinking of for ours. If we are becoming, almost in spite of ourselves, a body of national importance, if we have now nearly

700 members, it certainly becomes a question whether we ought not to adopt some such plan, so that the wider circle of those members who cannot come to our regular meetings may take part in our discussions. In that way it is believed that we might also get from them much that would be valuable for ourselves.

It has seemed to me, watching things as your executive officer for the last year, that on the whole the arrangements for our meetings are fairly good. If we come in punctually at one o'clock, and if our luncheon is served as rapidly as it should be, we still have time enough left for other things before the afternoon has gone and members must take trains for suburban cities or towns. But it is important that we shall be able to begin *punctually* at one, and also, of course, that the luncheon shall be quickly served.

Although often dealing with sanitary matters, we have not infrequently met under most unsanitary conditions, in rooms overheated as they used to be at Young's Hotel, and ill ventilated as has often been the case here. This matter requires very careful attention, for if one is to go home from a meeting refreshed and not tired out so that he isn't good for much the next day, it is highly important that he should have fresh air and not be overheated during the afternoon. And this raises a question which you must often have thought of, and which I have often thought of, viz., whether in this metropolis of New England we haven't now reached the time when all our engineering and scientific societies and perhaps some others, should get together and have a building of their own, a club house, if you like, with rooms for dining and with rooms for resting and sitting about and smoking and talking, — for the social side of our work, which is quite as important as the reading of papers.

I know that this question has been discussed in the past and dismissed as impracticable, but New England is getting larger all the time, associations are multiplying, wealth is increasing, and it does seem to me that the time ought to be very near, if it has not now arrived, when we should have in Boston, as they have in New York, a building adapted for work of our kind. We shall need such a building more in the future than we do to-day. While our hotels are good to us and do the best they can under

the circumstances, we ought to have rooms ventilated with the latest appliances, so that when smoke forms here it shall be carried away, as it is, for example, in the Hotel St. Regis, in New York. If you have ever dined there and seen people smoking in the dining room with ladies, — smoking anywhere, without any odor of smoke remaining in the room, — you know what good ventilation to-day is. But most people do not know, and many who do know do not seem to care. We ought to have a building used by all the scientific societies, ventilated in the latest and best way, in charge of a janitor who should be well paid and who wouldn't overheat it, but would manage things as any scientific expert who has studied the subject could tell him how to manage them. Then we could sit through one of our meetings and go out, not with a full head — yes, I hope with a full head, but not with a headache — and refreshed by good ventilation, rather than wearied by overheating and poor ventilation.

Our year has certainly been a successful one, and the editor will tell you about the JOURNAL. It seems to me that the JOURNAL is something which we want to foster with the greatest care. It is from this that our absent members get their money's worth. They get the JOURNAL, they know what has been going on, and they get the benefit of all the papers presented. The question is whether we ought not to extend the scope of the JOURNAL somewhat, whether we ought not to seek to publish still more papers of general interest relating to water and water supplies; and it seems to me that as long as we have editors such as we have thus far always had, careful and patient workers, we might afford, perhaps, to put more money into the JOURNAL, — which means into the salary of the editor and into the printing, — and extend our work somewhat in that direction, gradually perhaps, at first, but considerably later.

You remember that the American Water Works Association met here during the summer, and that our relations with the officers and members were of the most agreeable character. Your President spoke for our Association at the opening meeting in Huntington Hall, and the meeting of that Association in what we may consider our own territory was most welcome to us, and I believe most agreeable to the members of that organization. It

was at the same time very successful. There need be and should be no conflict whatever between these two bodies, — the larger national association covering the whole of these United States from the Atlantic to the Pacific and from Canada to Mexico, and the New England Association having a strong local basis here in New England but reaching out as far as experience and the demand show it wise to reach.

Two or three legislative matters of interest have come up during the year, one of them being the matter of boating on Great Ponds, in which our Association threw its influence in favor of the protection of the water supplies of the state, as I hope it may always continue to do. Another was a resolution and an effort in support of the hydrographic work of the United States Geological Survey; and the third an attempt to aid those who are seeking to provide a forest reservation in the White Mountains — something which means so much to us in connection not only with water supply but also with water power.

And that leads me to say, gentlemen, that our Association, it seems to me, runs a little too much to water supplies, municipal water supplies, and not quite enough to other aspects of water works, — to water for fire protection and especially to water powers. New England is full of water powers and there are many interesting questions coming up which we ought to hear more about from time to time than we have thus far heard at our meetings.

It would be easy for me to take up all the afternoon in talking about the past and the future of the Association, but I will spare you, simply remarking that never was there a time, perhaps — I think I may even omit the " perhaps " — never was there a time when questions of water supply and water power were more important than they are to-day, — of water supply because of the growth of city populations. The terrible epidemics of typhoid fever to-day in Scranton and in Pittsburg, Pa., lend point to my statement in that direction. The value of power in every direction to-day, the demand for power, the possibilities of profit in power, likewise make the subject of water power more important than ever before.

There is, then, ample room for our Association, ample room

for its further growth and extension, and if we all keep up our loyalty to it, if we all strive to work for it as we ought to do, there is no reason why its membership and influence should not continue to increase. I think, however, we want to beware of one thing. All of us are who busy, — and who of us is not? — naturally wish and expect the officers of the Association to take all the trouble, to run it, and to look out for its interests. That is a comprehensible point of view with any one who is busy. But the Association will never reach its highest usefulness until every member of it feels his individual duty toward it, particularly with respect to helping out as to its work and as to its programs. It is conceivable that we might have a large program-committee which should be a kind of drag-net especially devised for getting those practical experience papers upon which I have harped so long and so often, and which do not seem to be readily forthcoming. If every one of us does his duty by the Association he will get out of it even more than he puts into it, for after all that is about what we do in this world: we get out of things very much what we put into them, and if a man will put work into the Association and devotion and affection, he will be likely to reap a rich reward from it.

There came in during the year one letter which I should have read at an earlier meeting, but which now I am rather glad I did not read before. It seems we have a member in Plymouth, Mass., eighty-five years old, who has a real and abiding regard for this Association. I haven't the pleasure of his acquaintance myself, but his name is Bagnell. He writes to the Secretary in a very good hand as follows, — and if all of us at the age of eighty-five are able to write letters in his spirit we shall be testifying, as this writer does, to a deep regard for the Association:

" WILLARD KENT:

" *Dear Sir,* — I suppose my membership in the Association is closed. It is just as well. I am getting along in years. I was born in the year 1822. I am in the doctor's hands and have been for the last four months. I shall never go out of Plymouth again until I go across the silent river. I send my last year's dues so I can be square with the world, and so I can die happy.

God bless the New England Water Works Association. Yours until death, R. W. BAGNELL, Plymouth."

[Applause.]

In this touching and affectionate testimony from an old member it seems to me we see an example of what we may all strive ourselves to give, and an attitude which we may all strive ourselves to imitate. [Applause.]

PROFESSOR KINNICUTT. Mr. President, I think we have all listened with a great deal of pleasure to this letter from Mr. Bagnell, and I move that the Secretary be directed to transmit to him the cordial greeting of the Association, and the request that he remain a life member, all future dues being remitted. [Applause.]

THE PRESIDENT. The motion is made and seconded, and I am sure that every man of us will be glad to vote for it. I do not need to ask for any remarks, but will simply put the motion. [Adopted unanimously.]

MR. COGGESHALL. It may be proper for me to state that Mr. Bagnell was one of the 18 who organized this Association in Young's Hotel, in June, 1882.

REPORT OF SECRETARY.

The Secretary submitted the following report:

Mr. President and Gentlemen of the New England Water Works Association, — I have the honor to submit the following report of membership, receipts, and disbursements of the New England Water Works Association for the year ending December 31, 1906.

MEMBERSHIP.

The total membership of the Association, January 1, 1906, was	645
The present membership is	684
A net increase during the year of	39

MEMBERS.

January 1, 1906.	Total members		584
	Withdrawals:		
	Resigned	8	
	Died	4	
	Transferred to Honorary Membership	3	
	Dropped	38	53
	Carried forward		531

	Brought forward			531	
	Initiations:				
	January	3			
	February	12			
	March	6			
	June	8			
	September	11			
	November	7			
	December	17	64		
	Two members elected in 1905, but qualified in 1906		2	66	
	Reinstated:				
	Members dropped in 1905		9		
	Members dropped in 1906		12	21	618

HONORARY MEMBERS.

January 1, 1906.	Honorary members	8		
	Died	1	7	
	Transferred from membership	—	3	
	Elected		5	15

ASSOCIATES.

January 1, 1906.	Total associates		53	
	Withdrawals:			
	Resigned	4		
	Dropped	4	8	
			45	
	Initiations:			
	January	1		
	September	2	3	
	Reinstated:			
	Associates dropped in 1906		3	51
January 1, 1907.	Total membership			684

Summary of Receipts and Disbursements of the New England Water Works Association for the Year 1906.

RECEIPTS.

Initiations		$283.00
Annual dues:		
Members	$1 746.00	
Associates	765.00	
Fractional Dues:		
Members	49.00	
Associates	10.00	
Past Dues	68.20	
Total dues		2 638.20
Carried forward		$2 921.20

Brought forward,	$2 921.20
Advertisements	1 756.25
Subscriptions	184.00
Journals sold	164.85
Sundries	247.88
	$5 274.18

DISBURSEMENTS.

Journal	$1 514.37
Stationery	556.57
Assistant Secretary	540.00
Rent	400.00
Editor	300.00
Advertising Agent	255.00
Incidental expenses	222.20
Secretary	200.00
Reprints	166.30
Ladies' Complimentary lunch	147.50
Stenographer	126.50
Membership list	116.00
Stereopticon	93.20
Music	80.00
Printing pipe specifications	79.75
Badges	30.00
Insurance	15.00
Library	2.75
Total	$4 845.14
Receipts in excess of expenditures	$429.04

At the present time there is due the Association:

For advertisements	$81.25
For initiations and dues	34.00
For Journals	11.00
For specifications	1.40
	$127.65

I know of no outstanding bills against the Association.

Respectfully submitted,

WILLARD KENT, *Secretary*.

On motion of Mr. M. F. Collins, the report of the Secretary was accepted and ordered to be printed and placed on file.

Report of Treasurer.

The Treasurer submitted the following annual report:

LEWIS M. BANCROFT, TREASURER,
In account with the New England Water Works Association.

RECEIPTS.

1906				
Jan. 5	Balance on hand		$2 888.73
Aug. 1	Dividend, Peoples Savings Bank		53.16
Dec. 1	Dividend, Mechanics Savings Bank		39.60
Feb. 12	Rec'd of Willard Kent, Sec'y,	$959.60	
April 6	" " " "	1 544.46	
June 6	" " " "	402.30	
July 30	" " " "	495.77	
Sept. 20	" " " "	225.87	
Oct. 6	" " " "	201.00	
Dec. 13	" " " "	913.65	
1907			
Jan. 5	" " " "	531.53	5 274.18
			$8 255.67

EXPENDITURES.

Paid bills, as per itemized statement		$4 845.14
BALANCE ON HAND.		
Deposit Peoples Saving Bank, Worcester	$1 559.21	
Deposit Mechanics Savings Bank, Reading	1 161.95	
Deposit First National Bank, Reading	157.84	
Cash on hand	531.53	
		3 410.53
		$8 255.67

READING, MASS., January 5, 1907.

LEWIS M. BANCROFT, *Treasurer.*

DETAILED STATEMENT OF BILLS PAID.

1906.		
January 27	W. N. Hughes, envelopes and printing	$89.25
	D. Gillies' Sons, printing	4.75
	Harry L. Thomas, expenses auditing accounts . .	2.70
	R. C. P. Coggeshall, expense auditing accounts .	4.40
	W. W. Robertson, expense auditing accounts . . .	4.56
	Thomas P. Taylor, stereopticon	10.00
February 13	Miss J. M. Ham, assistant secretary, salary, January, 1906	45.00
March 5	Hub Engraving Company, plates	21.12
	L. M. Bancroft & Son, treasurer's bond	15.00
	William E. Whittaker, tracings	3.50
	Samuel Usher, standard specifications	32.50
	Miss Rosetta Key, singing, February 14	25.00
	W. N. Hughes, postal cards and printing	8.25
	Miss J. M. Ham, salary for February	45.00
	Helen S. Patterson, cards	36.00
16	Hub Engraving Company, plate	3.60
	D. Gillies' Sons, letter heads and envelopes . . .	81.34
	Boston Society of Civil Engineers, rent to February 28	100.00
	Charles W. Sherman, salary to April 1	75.00
	Charles W. Sherman, postage, etc.	4.94
April 6	Robert J. Thomas, services, advertising agent, to April 1	73.75
	Samuel Usher, March Journal	351.05
	Willard Kent, salary to April 1, 1906	50.00
	Willard Kent, music, guest tickets, etc.	100.50
	B. D. B. Bourne, stereopticon	10.00
	Miss J. M. Ham, salary for March	45.00
26	Samuel Usher, reprints	38.00
	Bacon & Burpee, reports of January and March meetings	26.50
	W. N. Hughes, printing circulars	2.75
	William E. Whittaker, tracings	3.50
	Miss J. M. Ham, salary for April	45.00
May 5	Samuel Usher, list of members	116.00
	Hub Engraving Company, plates	28.52
19	D. Gillies' Sons, printing	4.00
	W. N. Hughes, printing and binding	49.55
June 7	Miss J. M. Ham, salary for May	45.00
	Miss J. M. Ham, postage, telephone, express . . .	45.15
	Amount carried forward	$1 646.18

	Amount brought forward	$1 646.18
June 7	Miss J. M. Ham, copying for Meter Rates Committee	1.75
	Samuel Usher, standard specifications	47.25
8	The Brunswick	3.00
25	W. N. Hughes, printing tickets	2.25
	Chas. W. Sherman, salary three months to July 1	75.00
	Chas. W. Sherman, postage and express	6.50
	Miss J. M. Ham, salary for June	45.00
	R. J. Thomas, services advertising agent to July 1,	62.25
	Willard Kent, salary to July 1, 1906	50.00
	Willard Kent, guest tickets, postage and express	17.50
July 23	Samuel Usher, June JOURNAL	312.80
	W. N. Hughes, cash book	12.00
	J. M. Ham, salary for July (part)	35.00
September 7	Samual Usher, reprints	50.05
	W. N. Hughes, envelopes and printing	38.00
	Boston Society of Civil Engineers, rent to May 31,	100.00
	D. Gillies' Sons, printing	14.60
	J. M. Ham, bal. July and August, salary	55.00
24	O. G. Barron, postals	7.00
	The Somerville Journal Company, printing	1.50
	Charles W. Sherman, salary to October 1	75.00
	Charles W. Sherman, postage on JOURNAL	5.00
	Samuel Usher, reprints	1.50
	Willard Kent, salary to October 1, 1906	50.00
	Willard Kent, cash paid account of Annual Convention	184.00
	Frank E. Merrill, expense paid acc't T. P. Taylor	18.00
October 8	W. N. Hughes, letter heads	5.00
	Boston Regalia Company, badges	30.00
	Thomas P. Taylor, stereopticon	35.20
	J. M. Ham, salary for September	45.00
	D. Gillies' Sons, programs	13.50
24	Miss A. N. Hill, typewriting for Committee on Uniformity of Hydrants and Valves	4.85
	Hub Engraving Company, plates	50.68
	Wm. E. Whittaker, tracings	8.50
	Bacon & Burpee, report of September meeting	76.25
November 3	Boston Society of Civil Engineers, rent to August 31,	100.00
	Miss J. M. Ham, salary for October	45.00
	Miss J. M. Ham, sundry expenses	82.20
22	Hub Engraving Company, plate	1.18
	Samuel Usher, September JOURNAL	389.15
	Amount carried forward	$3 802.64

	Amount brought forward	$3 802.64
November 22	R. J. Thomas, services, advertising agent to November 1	61.75
	J. B. Fillebrown, music, November meeting	10.00
	Thomas P. Taylor, stereopticon, November 14	10.00
	Miss J. M. Ham, salary for November	45.00
December 12	Samuel Usher, reprints	43.00
	Hub Engraving Company, plates	17.20
	Wm. E. Whittaker, tracings	3.50
	D. Gillies' Sons, circulars	12.50
29	Hub Engraving Company, Plates	13.91
	Boston Society of Civil Engineers, rent to December 1, 1906	100.00
	W. N. Hughes, printing	11.00
	Charles W. Sherman, coypright and postage	2.00
	Chas. W. Sherman, salary to December 31, 1906	75.00
	Thomas P. Taylor, stereopticon	10.00
	Miss J. M. Ham, salary to December 31, 1906	45.00
	Miss J. M. Ham, express, telephone, etc.	32.48
	Bacon & Burpee, reporting November and December meetings	23.75
	Willard Kent, salary to December 31, 1906	50.00
	Willard Kent, sundry expenses	34.00
1907.	Samuel Usher, printing December JOURNAL and reprints	344.66
January 5	D. Gillies' Sons, circulars	14.50
	R. J. Thomas, services advertising agent to January 1, 1907	57.25
	La Rue Viedenburg, services	10.00
	Prof. Geo. N. Cross, lecture on White Hills	16.00
		$4 845.14

On motion of Mr. Frank L. Fuller, the report of the Treasurer was accepted and ordered to be placed on file.

REPORT OF EDITOR.

The Editor submitted the following as his annual report:

BOSTON, January 9, 1907.

To the New England Water Works Association, — The following is my report for the year 1906, as editor of the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

The accompanying tabular statements show in detail the amount of material in the JOURNAL; of receipts and expenditures on account of the JOURNAL

for the past year; and a comparison with the conditions of the six preceding years.

Size of Volume. — The volume is considerably smaller than that of the preceding year, as the latter had an unusual amount of material presented at the New York Convention. It is, however, larger than any other preceding volume of the JOURNAL. In comparison with this statement, it is gratifying to note that the gross cost is less than that for the three preceding years, and that the net cost, considering the size of the Association and number of pages, less than ever before since these reports have been made.

Illustrations. — The total cost of illustrations in the JOURNAL for the year has been $271.71, or 10.6 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge. Some free reprints have also been furnished to members who have contributed important discussions which practically amounted to papers in themselves. The net cost to the Association of the reprints has been $91.55, or $3.98 for each of the 23 papers published during the year.

Circulation. — The present circulation of the JOURNAL is:

Members (all grades)	684
Subscribers	60
Exchanges	23
Total	767

an increase of 62 over the preceding year.

Advertising. — The December issue contained 26.08 pages of paid advertising, which if maintained throughout a year would mean an annual income from this source of $1 740. A year ago the figures were 28.08 and $1 985, showing a considerable decrease during the year.

Pipe Specifications. — During the year pipe specifications have been sold to the amount of $132.10; the expense for reprinting specifications during the year has been $79.75, leaving a net gain of $52.35 for the year. Our net income from this source a year ago was $56.70, so that the total net income at the end of 1906 has been $109.05. Of course the original cost of typesetting and illustrating these specifications was charged to the JOURNAL in which the specifications were first published, but the net receipts have now been sufficient to practically repay this expense. We still have on hand a fair supply of the specifications, enough, if sold at retail, to bring in some $40, more or less.

I know of no outstanding bills against the Association on account of the JOURNAL.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor.*

TABLE No. 1.

STATEMENT OF MATERIAL IN VOLUME XX, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1906.

Number.	Date.	Pages of Papers.	Proceedings.	Total Text.	Index.	Advts.	Cover and Contents.	Inset Plates.	Total.	Cuts.
1	March	97	29	126	–	31	4	8	169	9
2	June	98	12	110	–	28	4	6	148	10
3	September	125	17	142	–	28	4	12	186	6
4	December	108	9	117	7	28	4	3	159	16
	Total	428	67	495	7	115	16	29	662	41

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XX, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1906.

Receipts.		Expenditures.	
From advertisements . . .	$1 756.25	For printing JOURNAL .	$1 539.16
From sale of JOURNALS . .	164.85	For preparing illustrations	155.21
From sale of reprints . . .	74.75	For editor's salary . . .	300.00
From sale of cuts	5.80	For editor's incidentals .	31.44
From subscriptions	184.00	For advertising agent's commissions	255.00
	$2 185.65	For reporting	126.50
Net cost of JOURNAL . . .	$387.96	For reprints and advance copies	166.30
	$2 573.61	Gross cost of JOURNAL . .	$2 573.61

TABLE No. 3.

COMPARISON BETWEEN VOLUMES XIV, XV, XVI, XVII, XVIII, XIX AND XX, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	VOL. XIV. 1899–1900.	4 NUMBERS OF VOL. XV. 1900–1901.	VOL. XVI. 1902.	VOL. XVII. 1903.	VOL. XVIII. 1904.	VOL. XIX. 1905.	VOL. XX. 1906.
Edition (copies)	1 100	1 200	1 200	1 200	900	900	900
Average membership	583	586	571	587	596	625	665
Pages of text	345	363	403	430	491	587	495
Pages of text per 1 000 members,	600	618	707	733	824	939	745
Total pages, all kinds	485	536	584	619	794*	784	662
Total pages per 1 000 members	832	913	1 020	1 051	1 332	1 254	995
GROSS COST:							
Total	$1 954.15	$2 194.26	$2 439.99	$2 706.05	$2 928.77	$3 266.65	$2 573.61
Per page	4.03	4.10	4.18	4.38	3.69	4.17	3.88
Per member	3.35	3.75	4.27	4.61	4.91	5.23	3.87
Per member per 1 000 pages	6.91	6.99	7.32	7.46	6.18	6.67	5.85
Per member per 1 000 pp. text,	9.71	10.31	10.60	10.72	10.00	8.91	7.81
NET COST:							
Total	$347.55	$332.90	$622.89	$770.62	$648.11	1 072.95	$387.96
Per page	.72	.62	1.07	1.25	.82	1.37	.58
Per member	.60	.57	1.09	1.31	1.09	1.72	.58
Per member per 1 000 pages	1.23	1.06	1.87	2.12	1.30	2.20	.88
Per member per 1 000 pp. text,	1.73	1.57	2.71	3.05	2.22	2.93	1.18

* Including General Index.

On motion of Mr. George A. Stacy the report was accepted and ordered placed on file.

Report of Finance Committee.

In the absence of Mr. Harry L. Thomas, Chairman, on account of illness, the report of the Finance Committee was read by Mr. Maybury as follows:

BOSTON, MASS., January 5, 1907.

We, the undersigned, members of the Finance Committee of the New England Water Works Association, met this day with your Secretary and Treasurer at the headquarters of the Association, and attended to the duties devolving upon us.

We examined the Secretary's book, verified additions, and found the total receipts $5 274.18, as stated, to be correct. This amount he has turned over to the Treasurer, as his vouchers testify.

We have examined the Treasurer's accounts and found that his receipts from the Secretary agree with the amount as above stated. We have also examined the record of his payments, and find them correctly recorded, and properly certified and vouched for. These disbursements amount to $4 845.14.

We find the invested funds in two savings banks to be $2 721.16, and the cash on hand to be $689.37, all as stated in the Treasurer's report, making a total of $3 410.53 as a balance on hand for the beginning of the new year.

WILLIAM E. MAYBURY,
ARTHUR D. MARBLE,
Finance Committee.

On motion of Mr. R. P. C. Coggeshall the report was accepted and ordered to be printed.

Election of Officers.

(REPORT OF TELLERS OF ELECTION.)

Boston, Mass., January 9, 1907.

Mr. President, — The tellers appointed to canvass the ballots for the election of officers of the New England Water Works Association, for the year 1907, beg leave to report as follows:

Whole number of votes cast	207
Blank	6
Not properly endorsed	11
For President.	
John C. Whitney	196
William T. Sedgwick	1
For Vice-Presidents.	
M. N. Baker	197
J. M. Birmingham	196
George H. Snell	196
V. C. Hastings	196
George A. King	196
H. T. Sparks	196
For Secretary.	
Willard Kent	196
For Editor.	
Charles W. Sherman	197
For Advertising Agent.	
Robert J. Thomas	197
For Additional Members of Executive Committee.	
A. E. Martin	196
D. N. Tower	197
George W. Batchelder	197
C.-E. A. Winslow	1
For Finance Committee.	
Arthur D. Marble	198
William E. Maybury	198
George Cassell	197
For Treasurer.	
Lewis M. Bancroft	197

Rsepectfully submitted,

J. C. HAMMOND, Jr.,
ERMAN M. PECK,

Tellers.

The President announced the election of the various officers as shown by the return of the tellers, and said he was sure all the members desired to hear a word from the incoming president, Mr. Whitney. Mr. Whitney was greeted with loud applause and responded briefly, as follows:

Mr. President, — I thank you sincerely for your kind introduction, and I wish to assure you and all the members of the Association that with the assistance of all the members it is hoped that we may during the coming year maintain the high standard which has been set for us by previous presidents and officers, and that in the future the Association may continue to rank, as it does now, as the foremost society of its kind in the world. [Applause.]

The following applicants having been recommended by the Executive Committee, were elected to membership:

Chester H. Wells, Montclair, N. J., health officer; F. J. Hoxie, Phenix, R. I., engaged in general hydraulic work; Charles F. Eveleth, South Lincoln, Mass., mechanical engineer; Ralph E. Tarbett, Knoxville, Tenn., bacteriologist and engineer connected with the Knoxville Water Company.

The paper for the afternoon was read by Arthur N. French, superintendent of Water Company, Hyde Park, Mass., the subject being "Meter Registration." Messrs. J. A. Tilden, George A. Stacy, Edwin C. Brooks, George H. Snell, John C. Whitney, John H. Flynn, and J. C. Hammond, Jr., participated in the discussion which followed.

Dr. Langdon Frothingham, of the Harvard Medical School, gave a brief talk on Hydrophobia.

Adjourned.

February Meeting.

Hotel Brunswick,
Boston, February 13, 1907.

Mr. John C. Whitney, president, in the chair.

The following members and guests were present:

Honorary Members.

W. T. Sedgwick, F. W. Shepperd. — 2.

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, W. T. Barnes, G. W. Batchelder, J. W. Blackmer, E. M. Blake, Dexter Brackett, E. C. Brooks, C. E. Childs, George Cassell, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. H. Cook, J. W. Crawford, G. E. Crowell, John Doyle, B. R. Felton, C. R. Felton, J. N. Ferguson, F. F. Forbes, W. E. Foss, A. N. French, F. L. Fuller, A. S. Glover, F. E. Hall, J. O. Hall, E. A. W. Hammatt, G. W. Hawkes, H. G. Holden, J. L. Howard, H. R. Johnson, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, L. P. Kinnicutt, C. F. Knowlton, E. S. Larned, F. A. McInnes, Hugh McLean, H. V. Macksey, N. A. McMillen, D. E. Makepeace, F. E. Merrill, H. A. Miller, William Naylor, O. E. Parks, E. M. Peck, T. A. Peirce, J. H. Perkins, H. E. Royce, G. A. Sanborn, E. M. Shedd, C. W. Sherman, H. W. Sanderson, W. F. Sullivan, L. A. Taylor, R. J. Thomas, H. L. Thomas, W. H. Thomas, L. D. Thorpe, D. N. Tower, J. A. Tilden, W. H. Vaughn, R. S. Weston, J. C. Whitney, O. J. Whitney, G. E. Wilde, F. I. Winslow, G. E. Winslow. — 73.

Associates.

Builders Iron Foundry, by F. N. Connet; Coffin Valve Company, by H. L. Weston; The Fairbanks Company, by F. A. Leavitt; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, and W. A. Hersey; National Water Main Cleaning Company, by G. F. Whitney and A. P. Foster; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Union Water Meter Company, by F. L. Northrop; United States Cast Iron Pipe and Foundry Company, by Frank W. Nevins; R. D. Wood & Co., by Walter Wood and William F. Woodburn. — 21.

GUESTS.

Hon. Sidney B. Kane, Somerville, Mass.; Arthur C. King, Taunton, Mass.; W. E. Rawson, Uxbridge, Mass.; E. A. Blackmer, Plymouth, Mass.; John C. DeMello, Jr., general foreman, New Bedford, Mass.; M. F. Wright, Butler, Pa.; F. L. Clapp, Stoughton, Mass.; E. P. Byrne, city engineer, Medford, Mass.; H. E. Cowan, J. E. Taylor, William Lyman Underwood and A. G. Norton, Boston, Mass. — 12.

[Names counted twice — 4.]

The Secretary presented applications for membership, properly endorsed and recommended by the Executive Committee, from the following:

Charles Saville, Waban, Mass., assistant in the engineering department of the Massachusetts State Board of Health; Charles H. Rollins, Watertown, Mass., member of the Board of Water Commissioners, Watertown; George C. Bunker, Charleston, S. C., biologist and chemist, city of Charleston; Halsey French, New York, assistant engineer, Board of Water Supply, New York City; M. G. Hall, Centerville, Ia., superintendent of water works, Centerville.

On motion of Mr. Fuller the Secretary was instructed to cast one ballot in favor of the applicants named, and they were declared duly elected members of the Association.

The President presented a letter from an absent member, asking for experience with "Universal" cast-iron pipe. Messrs. John H. Cook, Charles W. Sherman, and Wm. R. Conard spoke upon this subject.

At this point the President called upon Mr. William R. Conard, of Burlington, N. J., who presented a paper entitled "Some Observations on Cast-Iron Pipe Specifications." The paper was discussed by Frank A. McInnes, Wm. E. Foss, John Doyle, Frank L. Fuller, and Walter Wood.

William Lyman Underwood, Esq., lecturer in the biological department of the Massachusetts Institute of Technology, gave a talk on the work of river drivers in the Maine woods, illustrated by stereopticon views.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, December 12, 1906, at 11.30 A.M.

Present: President Sedgwick and members, Charles W. Sherman, John C. Chase, Robert J. Thomas, Lewis M. Bancroft, Frank E. Merrill, and Willard Kent.

The following applications, twenty-three in number, were received and recommended for membership: John W. Maxcy, consulting engineer, Houston, Tex.; Arthur B. Cleaveland, United States Reclamation Service, Orman, S. D.; Albert L. Sawyer, water registrar, Haverhill, Mass.; E. F. Kitson, civil engineer, Norfolk, Va.; Nathaniel W. Hayden, president and manager, Windsor Water Company, Windsor, Conn.; Charles F. Breitzke, White Plains, N. Y.; Perkins Boynton, chemist, East Jersey Water Company, Little Falls, N. J.; William H. Beers, Jr., bacteriologist, Water Department, Columbia, N. C.; William L. Butcher, State House, Boston, Mass.; W. F. Currier, chemist, Philadelphia, Pa.; Herbert C. Emerson, M.D., Springfield, Mass.; Frederick W. Farrell, bacteriologist, Emerson Laboratory, Springfield, Mass.; Selskar M. Gunn, assistant bacteriologist, Iowa State Board of Health, Iowa City, Iowa; August E. Hansen, sanitary engineer, New York City; John H. McManus, assistant engineer, Board of Water Supply, City of New York, West Hurley, N. Y.; James A. Newlands, chemist, Connecticut State Board of Health, Middletown, Conn.; Burton G. Philbrick, water sanitarian with Lederle Laboratory, Brooklyn, N. Y.; Henry A. Pressey, Washington, D. C.; William J. Roberts, professor of civil engineering, State Agricultural College, Pullman, Wash.; Louis J. Richards, health officer, Board of Health, Elizabeth, N. J.; Luther R. Sawin, bacteriologist, New York Water Department, Mt. Kisco, N. Y.; L. R. Thurlow, health officer, Plainfield, N. J.; Alex. J. Taylor, engineer, Sewer Department, Wilmington, Del.

Voted: That three members and two associates dropped for non-payment of dues, who have since forwarded amount of dues, be reinstated to former membership.

Voted: That the following resolution be presented to the Association.

[Resolution printed on page 76.]

The place of the next Annual Convention was considered and the subject referred to a later meeting.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., January 9, 1907, at 11.30 A.M.

Present: President William T. Sedgwick, and members John C. Chase, James L. Tighe, Robert J. Thomas, Lewis M. Bancroft, Frank E. Merrill, Charles W. Sherman, George A. Stacy, and Willard Kent.

Four applications were received and recommended for membership, viz., Charles F. Eveleth, South Lincoln, Mass.; F. J. Hoxie, Phenix, R. I.; Chester H. Wells, Montclair, N. J.; Ralph E. Tarbett, Knoxville, Tenn.

Voted: That the subject of place of next annual convention be referred to the incoming Executive Committee with the recommendation that it be held within the limits of New England.

Voted: That the Secretary, Treasurer, Editor, and Advertising Agent be a Committee on Ladies' Day with full power to add to their number, and to act for the Executive Committee.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., January 24, 1907.

Present: President John C. Whitney, George A. King, D. N. Tower, George W. Batchelder, Robert J. Thomas, and Willard Kent.

The records of the last meeting of the Executive Committee were read and approved by vote.

On motion of Mr. Thomas, seconded by Mr. King, it was voted:

That the annual custom of inviting the attendance of ladies at the February meeting be dispensed with for that occasion of the present year.

Voted: That the President and Secretary be a committee to arrange program of papers for the February meeting.

Voted: That the President and Secretary be a committee to provide music for the February meeting.

The June meeting, annual convention, and subject of a general circular relating to membership were discussed and referred to a later meeting.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., February 13, 1907, at 11.30 A.M.

Present: President J. C. Whitney, and members Robert J. Thomas, L. M. Bancroft, D. N. Tower, George W. Batchelder, George A. King, Charles W. Sherman, and Willard Kent.

The records of the last meeting were read and approved.

Applications for membership were received from the following-named persons:

Charles Saville, engineering department, Massachusetts State Board of Health, Boston, Mass.; Charles H. Rollins, water commissioner, Watertown, Mass.; Halsey French, assistant engineer, Board of Water Supply, city of New York, N. Y.; George C. Bunker, biologist and chemist, city of Charleston, Charleston, S. C.; M. G. Hall, superintendent water works, Centerville, Ia.

These applications were considered, and it was voted to recommend them to the Association for election to membership. One other application was received and action thereon postponed.

On motion of Mr. Thomas, seconded by Mr. Bancroft, it was voted that the President and Secretary be, and hereby are, authorized to make the necessary arrangements for the June meeting of the Association.

A request from prominent members of the Association was received asking that the Treasurer of the Association be paid a

nominal salary of fifty dollars per annum; whereupon it was voted that the salary of the Treasurer for the year 1907 be fifty dollars.

On motion of Mr. Thomas, seconded by Mr. Batchelder, the salary of the Assistant Secretary for the year 1907 was increased to fifty dollars per month.

On motion of Mr. Batchelder, seconded by Mr. Thomas, the Secretary was authorized and instructed to investigate and report on the subject of a desirable place for holding the next annual convention.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXI. June, 1907. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

SOME NEW FACTS RELATING TO THE EFFECT OF METERS ON THE CONSUMPTION OF WATER.

BY WILLIAM S. JOHNSON, ASSISTANT ENGINEER, MASSACHUSETTS STATE BOARD OF HEALTH.

[*Read March 13, 1907.*]

For the past twenty years the advantages of selling water by meter have been much discussed, until now there are but few connected with the management of water works who question the desirability of having all services metered. There is much yet to be learned, however, as to the results to be accomplished. The enormous saving of water, and the consequent saving in expense which would be possible by the general use of meters, have been repeatedly demonstrated. The cities of Brockton, Fall River, and Providence, where meters have been in general use for many years, have been referred to time and time again as examples of what might be accomplished in other places. The English and German cities, with their still lower consumption, have also been frequently cited as examples of what ought to be accomplished in American cities.

During the past ten to twenty years great numbers of meters have been introduced, and now in many places the percentage of metered services is as great as in the cities which have so long served as examples, — but the predicted saving in water has not been accomplished. On the contrary, an examination of the figures of consumption shows that the rate of increase in the use of water in Brockton, Fall River, and Providence is greater than the rate

of decrease in many of the places where meters have recently been introduced, indicating that if the consumption in these other cities ever becomes the same as that of Brockton, Fall River, and Providence, the latter places are likely to meet the others half way.

Notwithstanding the great increase in the use of meters all over the country, the average quantity of water consumed per person is increasing at a rapid rate. The increase in the consumption of water during the past ten years is shown in the accompanying diagram, Fig. 1, which gives the average daily consumption in a large number of cities outside of New England and in the principal New England cities and towns. On the same diagram is shown the consumption of water in those places inside and outside of New England where, in 1895, at the beginning of the period, more than 25 per cent. of the services were metered, and the consumption in those places where the percentage of metered services has increased more than 25 during the ten years, — that is, where there has been a general introduction of meters.

We are struck, in the first place, by the great difference in the consumption of water in New England and in the cities outside of New England. This creditable showing we will explain as being due to the influence of the New England Water Works Association.

The startling feature of the diagram, however, is the apparent failure of meters to reduce the consumption of water, or even to check the increase. During this period of ten years there were installed in the places used in making these curves more than 250 000 meters. In the places used in making the averages outside of New England the percentage of metered services in 1895 was 13, while in 1905, at the end of the ten years, it had increased to 38. During this time there was an increase in the per capita consumption of water amounting to 11 gallons per day. In New England the percentage of metered services in 1895 was 40, increasing in the ten years to 60, while the consumption increased 15 gallons per person per day.

In those places outside of New England where more than 25 per cent. of the services were metered at the beginning of the period under consideration, the increase has been 14 gallons per day. In those places where there has been a very general introduction of meters during the period there has been a decrease of 1 gallon per

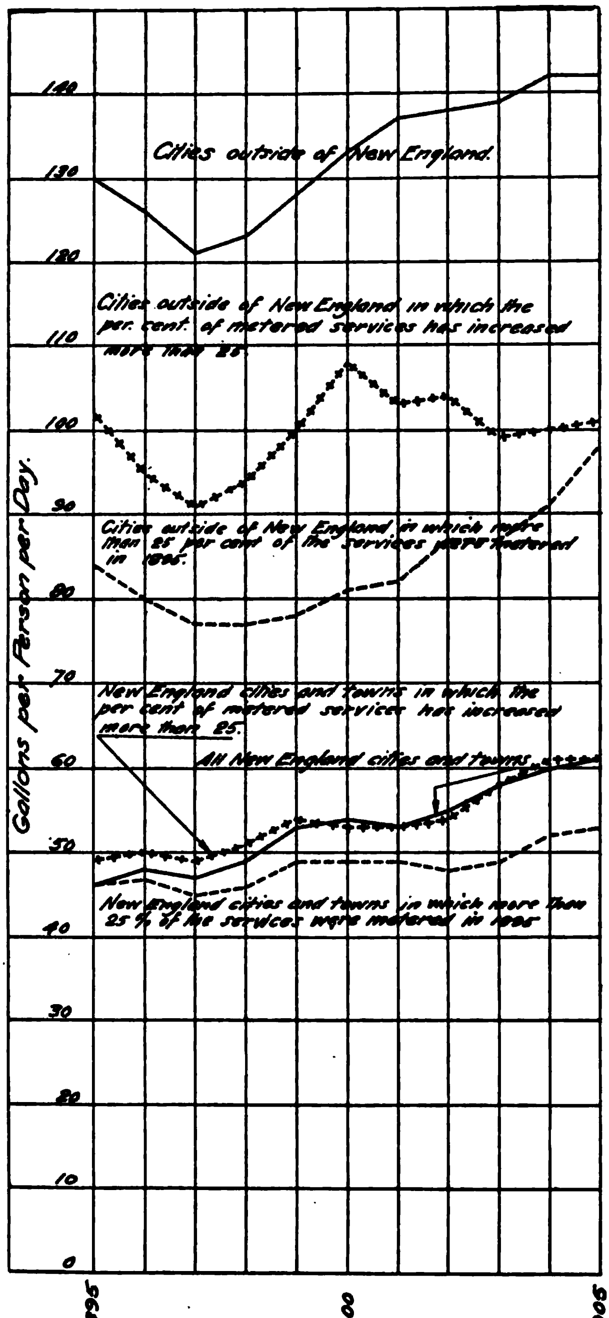

Cities outside of New England.
Cities outside of New England in which the per cent. of metered services has increased more than 25
Cities outside of New England in which more than 25 per cent of the services were metered in 1895.
New England cities and towns in which the per cent of metered services has increased more than 25.
All New England cities and towns.
New England cities and towns in which more than 25 % of the services were metered in 1895
Gallons per Person per Day.
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1895
1900
1905

FIG. 1.

person per day. In New England the increase in consumption in those places which were very generally metered in 1895 has been kept down to 6 gallons per person per day, while in those places where the percentage of metered services has increased more than 25 during the ten years the increase has been 11 gallons per person per day.

In Table No. 1 are given statistics in relation to the consumption of water and the percentage of metered services, in 1905, in American cities having a population of more than 25 000. In Table No. 2 are given similar statistics for places in Massachusetts having a population of less than 25 000. The population of places in Massachusetts is the 1905 census population; outside of Massachusetts, where the latest available census is that of 1900, the population has been estimated by assuming that the rate of increase from 1900 to 1905 has been the same as that from 1890 to 1900. In practically all cases the population used is the total population of the city supplied, the only exception being where a large community is supplied outside of the city limits. This figure does not in all cases represent the actual population using the water, as in some of the places there is a considerable percentage of the population to which the public water supply is not available. On the other hand, in places used as summer resorts, and in cities which are business centers for the surrounding population, the number of people actually using the water is much larger than the census population. It is found that the estimates of the population actually supplied with water are in many cases very inaccurate, and better comparative results are obtained by taking the total population of the places supplied. The figures for consumption and for meters have been obtained in all cases either from printed reports or from the officials in charge of the water works.

TABLE No. 1.

AVERAGE DAILY CONSUMPTION OF WATER AND PERCENTAGE OF METERED SERVICES IN 1905 IN CITIES HAVING A POPULATION OF MORE THAN 25 000.

City.	Population.	Per Cent. Metered Services.	Consumption. (Gallons per Person per Day.)
Albany, N. Y.	93 765	15	211
Altoona, Pa.	43 291	3	112
Atlanta, Ga.	102 041	100	65
Atlantic City, N. J.	35 229	78	147
Auburn, N. Y.	32 588	6	172
Augusta, Ga.	42 511	0	150
Bay City, Mich.	27 523	33	122
Bayonne, N. J.	39 566	100	95
Boston, Mass.	595 380	5	151
Bridgeport, Conn.	82 061	5	210
Brockton, Mass.	47 794	90	38
Buffalo, N. Y.	400 748	3	324
Butte, Mont.	40 343	7	100
Cambridge, Mass.	97 434	19	92
Camden, N. J.	84 746	3	155
Canton, Ohio	32 906	2	125
Cedar Rapids, Ia.	29 474	40	83
Charleston, S. C.	56 233	2	57
Chelsea, Mass.	37 289	10	110
Chester, Pa.	40 869	20	75
Cincinnati, Ohio	340 399	12	130
Cleveland, Ohio	441 974	68	137
Columbus, Ohio	144 265	76	110
Covington, Ky.	45 721	100	51
Davenport, Ia.	39 445	50	81
Dayton, Ohio	97 389	70	70
Detroit, Mich.	325 614	9	188
Duluth, Minn.	62 896	41	77
Erie, Pa.	58 783	2	179
Evansville, Ind.	63 132	0	125
Everett, Mass.	29 111	2	89
Fall River, Mass.	105 762	97	42
Gloucester, Mass.	26 011	5	53
Grand Rapids, Mich.	101 211	29	123
Harrisburg, Pa.	55 557	73	171
Hartford, Conn.	93 160	98	66
Hoboken, N. J.	67 222	69	115
Holyoke, Mass.	49 934	8	120

City.	Population.	Per Cent. Metered Services.	Consumption. (Gallons per Person per Day.)
Indianapolis, Ind.	196 028	10	82
Jackson, Mich.	27 371	26	74
Jacksonville, Fla.	34 043	59	67
Johnstown, Pa.	43 000	1	159
Kansas City, Kan.	57 969	45	113
Kansas City, Mo.	179 270	38	73
Knoxville, Tenn.	37 688	36	67
La Crosse, Wis.	30 797	5	96
Lancaster, Pa.	46 183	20	130
Lawrence, Mass.	70 050	88	43
Lexington, Ky.	28 770	98	58
Lincoln, Neb.	32 677	100	40
Los Angeles, Cal.	128 521	31	120
Louisville, Ky.	226 531	8	81
Lowell, Mass.	94 889	69	58
Lynn and Saugus, Mass.	83 295	30	59
Malden, Mass.	38 037	78	53
McKeesport, Pa.	40 970	23	115
Manchester, N. H.	63 417	72	52
Memphis, Tenn.	121 232	20	100
Milwaukee, Wis.	325 735	80	91
Minneapolis, Minn.	221 708	47	76
Nashville, Tenn.	283 213	52	148
Newark, N. J.	278 190	44	117
New Bedford, Mass.	74 362	23	95
New Britain, Conn.	30 737	6	145
Newcastle, Pa.	36 708	1	94
New Haven, Conn.	121 391	3	168
Newport, Ky.	29 992	20	37
Newton, Mass.	36 827	86	58
Norfolk, Va.	52 500	0	125
Omaha, Neb.	83 607	59	110
Oshkosh, Wis.	31 008	15	76
Paterson, N. J.	118 583	37	87
Pawtucket, R. I.	79 400	81	104
Philadelphia, Pa.	1 417 063	1	230
Pittsburg, Pa.	363 116	0	210
Providence, R. I.	212 823	86	68
Quincy, Ill.	38 631	53	31
Quincy, Mass.	28 076	3	109
Racine, Wis.	33 146	51	90
Reading, Pa.	89 111	7	128

City.	Population.	Per Cent. Metered Services.	Consumption. (Gallons per Person per Day.)
Richmond, Va.	86 881	44	150
Rochester, N. Y.	176 964	41	88
Rockford, Ill.	34 784	19	95
Saginaw, Mich.	40 357	8	200
St. John, N. B.	45 432	3	143
St. Joseph, Mo.	128 306	20	58
St. Louis, Mo.	636 972	7	92
St. Paul, Minn.	178 020	38	56
Salt Lake City, Utah	57 875	2	309
San Antonio, Tex.	61 145	10	132
San Francisco, Cal.	364 674	21	96
Schenectady, N. Y.	37 572	0	99
Seattle, Wash.	99 588	12	100
Sioux City, Ia.	30 764	61	35
Somerville, Mass.	69 272	19	89
South Bend, Ind.	43 089	8	102
Springfield, Ohio	41 432	12	85
Superior, Wis.	40 645	31	57
Tacoma, Wash.	38 568	10	72
Taunton, Mass.	30 967	46	62
Terre Haute, Ind.	39 901	19	70
Toledo, Ohio	157 015	70	75
Toronto, Can.	270 000	4	93
Troy, N. Y.	60 500	4	248
Utica, N. Y.	62 569	98	59
Waltham, Mass.	26 282	10	79
Wilmington, Del.	84 046	21	102
Woonsocket, R. I.	31 888	85	37
Worcester, Mass.	128 135	95	75
Yonkers, N. Y.	55 879	99	115
York, Pa.	40 165	3	63

TABLE No. 2.

Average Daily Consumption of Water and Percentage of Metered Services in 1905 in Cities and Towns in Massachusetts having a Population of Less than 25 000.

City or Town.	Population.	Per Cent. Metered Services.	Consumption. (Gallons per Person per Day.)
Andover	6 632	78	68
Arlington	9 668	22	81
Attleboro	12 702	100	43
Avon	1 901	1	40
Ayer	2 386	55	53
Belmont	4 360	100	61
Beverly	15 223	3	87
Billerica	2 843	59	28
Braintree	6 879	37	87
Bridgewater and East Bridgewater	9 923	9	21
Brookline	23 436	93	95
Canton	4 702	47	63
Clinton	13 105	86	41
Danvers and Middleton	10 131	2	81
Dedham	7 774	37	135
Easton	4 909	43	24
Fairhaven	4 235	45	79
Falmouth	3 241	1	73
Foxboro	3 364	46	63
Franklin	5 244	2	44
Gardner	12 012	6	80
Groton	2 253	99	28
Hyde Park	14 510	34	77
Ipswich	5 205	30	26
Lexington	4 530	2	66
Manchester	2 618	100	94
Mansfield	4 245	33	49
Marlboro	14 073	59	41
Maynard	5 811	78	45
Medford	19 686	8	98
Melrose	14 295	3	112
Merrimac	1 884	100	28
Methuen	8 676	78	43
Middleboro	6 888	47	38
Milford and Hopedale	14 153	19	65
Milton	7 054	100	46
Montague	7 015	4	81

City or Town.	Population.	Per Cent. Metered Services.	Consumption. (Gallons per Person per Day.)
Nahant	922	18	149
Nantucket	2 930	0	56
Natick	9 609	58	56
Needham	4 284	95	66
Newburyport	14 675	2	51
North Andover	4 614	74	43
North Attleboro	7 878	100	40
Norwood	6 731	55	64
Orange	5 578	64	27
Peabody	13 098	4	133
Reading	5 682	89	28
Revere	12 659	4	80
Rockport	4 447	2	81
Shirley	1 692	99	13
Stoneham	6 332	2	81
Stoughton	5 959	59	64
Tisbury	1 120	1	63
Walpole	4 003	47	86
Ware	8 594	100	41
Wareham	3 660	0	10
Watertown	11 258	94	70
Webster	10 018	48	34
Wellesley	6 189	100	47
Weston	2 091	81	31
Whitman	6 521	54	25
Winchendon	5 933	97	18
Winthrop	7 034	2	114
Woburn	14 402	2	103

In order to show the relation between the percentage of metered services and the consumption, Tables No. 3 and No. 4 are presented, giving the average consumption in those places having certain percentages of services metered.

TABLE No. 3.

AVERAGE CONSUMPTION OF WATER PER PERSON IN 1905 IN CITIES HAVING A POPULATION OF MORE THAN 25 000, ARRANGED IN GROUPS ACCORDING TO THE PERCENTAGE OF SERVICES WHICH ARE PROVIDED WITH METERS.

	Gallons per Day.
Average of 34 cities in which not more than 10 per cent. of the services are metered	146
Average of 23 cities in which more than 10 per cent. but less than 25 per cent. of the services are metered	97
Average of 18 cities in which more than 25 per cent. but less than 50 per cent. of the services are metered	89
Average of 14 cities in which more than 50 per cent. but less than 75 per cent. of the services are metered	89
Average of 19 cities in which more than 75 per cent. of the services are metered	72

TABLE No. 4.

AVERAGE CONSUMPTION OF WATER PER PERSON IN 1905 IN CITIES AND TOWNS IN MASSACHUSETTS HAVING A POPULATION OF LESS THAN 25 000, ARRANGED IN GROUPS ACCORDING TO THE PERCENTAGE OF SERVICES WHICH ARE PROVIDED WITH METERS.

	Gallons per Day.
Average of 26 cities and towns in which not more than 25 per cent. of the services are metered	77
Average of 12 cities and towns in which more than 25 per cent. but less than 50 per cent. of the services are metered	63
Average of 9 cities and towns in which more than 50 per cent. but less than 75 per cent. of the services are metered	45
Average of 22 cities and towns in which more than 75 per cent. of the services are metered	48

These tables show that there is a marked difference in the consumption of water in the places which are generally metered and in those places which are not metered, but they also show that the consumption of water in the larger cities, even in places which are generally provided with meters, is much in excess of that in Brockton and Fall River.

The foregoing tables show the consumption in 1905 as compared with the number of meters in use at that time, and include places which have been thoroughly metered for a long period. In many places meters have been generally introduced within a few years, and in order to show the immediate effect of the introduction of

meters Table No. 5 has been prepared, which gives the increase or decrease in the consumption of water as compared with the increase in the percentage of metered services in the period from 1890 to 1905, and in the five years from 1900 to 1905.

TABLE No. 5.

INCREASE IN THE CONSUMPTION OF WATER IN CITIES AND TOWNS DURING THE PERIODS FROM 1890 TO 1905, AND FROM 1900 TO 1905, COMPARED WITH THE INCREASE IN THE PERCENTAGE OF METERED SERVICES DURING THE SAME PERIODS.

Increase in Percentage of Metered Services.	1890 — 1905.		1900 — 1905.	
	Number of Places.	Increase in Consumption. Gallons per Person per Day.	Number of Places.	Increase in Consumption. Gallons per Person per Day.
Less than 10	27	36	95	7
10–25	25	10	33	1
25–50	16	9	12	6*
More than 50	11	14	4	17*

* Decrease.

This table shows the effect of the introduction of a large number of meters within a short period. As would naturally be expected, the immediate effect is a reduction in the quantity of water used; but while the introduction of more than 25 per cent. of metered services within five years reduces the consumption, the introduction of the same number of meters in a period of fifteen years does not prevent a substantial increase in the consumption. In other words, it would appear that after a certain amount of waste has been checked, the increase in the consumption continues notwithstanding the use of meters.

The accompanying diagrams, Figs. 2 to 13, show graphically the relation between the percentage of metered services and the per capita consumption of water in several typical cities. In Figs. 2 to 7 will be seen the increase in consumption in cities which are thoroughly metered, the increase in all cases being very substantial. This increase may be called the normal increase in the consumption with all reasonable precautions taken against waste.

In the case of Richmond, Fig. 8, is shown the effect of the intro-

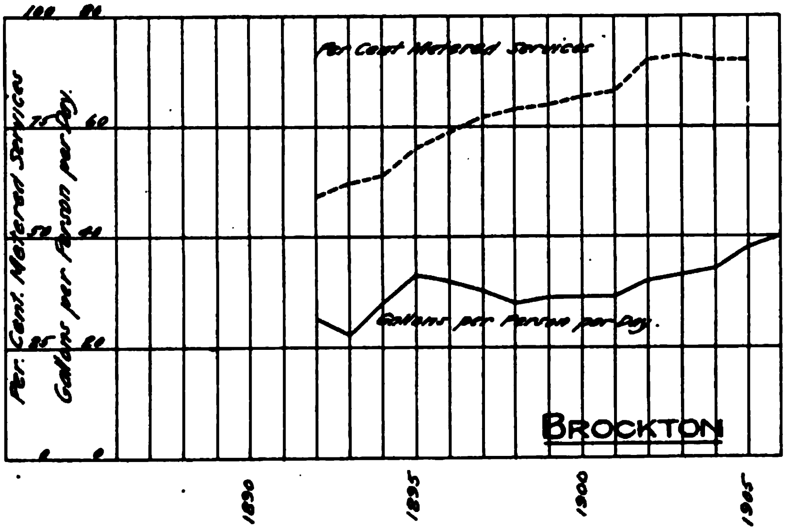

Per Cent Metered Services
Gallons per Person per Day.
Per. Cent. Metered Services
Gallons per Person per Day.
BROCKTON
1890
1895
1900
1905

FIG. 2.

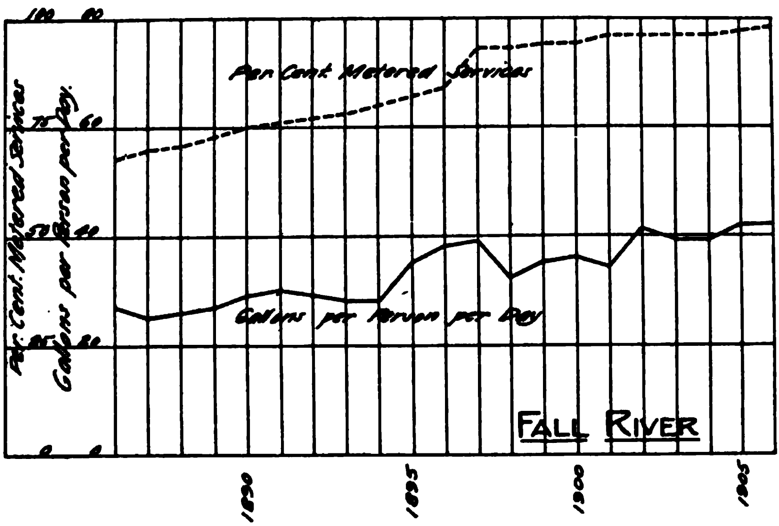

Per Cent Metered Services
Gallons per Person per Day
Per Cent. Metered Services
Gallons per Person per Day.
FALL RIVER
1890
1895
1900
1905

FIG. 3.

duction of meters on an abnormally large consumption, and this is a typical diagram. The immediate effect of the introduction of meters in such a place is to make a great reduction in the quantity of water used. The reduction continues for a few years until the principal sources of waste are discontinued, or possibly until the vigilance of the water department is somewhat abated, and then

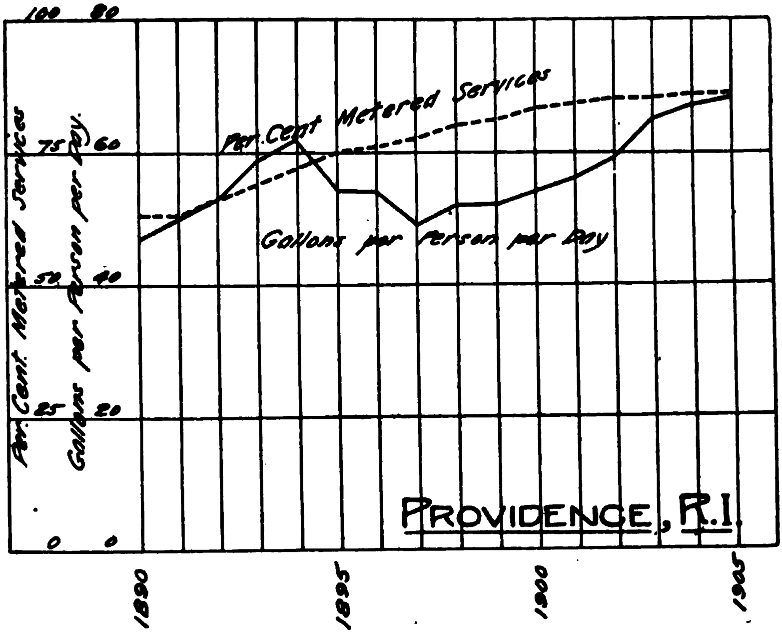


FIG. 4.

the increase in consumption again begins at substantially the same rate as before meters were introduced.

In Needham and Attleboro, Figs. 9 and 10, the introduction of meters appears to have failed to check the increase in the consumption.

The last three diagrams, Figs. 11, 12, and 13, show cases where the effect of meters may be overestimated, as there are other conditions which affect the quantity of water consumed. It is well

known that where the water supply is of poor quality a much greater quantity is used than where the water is clear and colorless, and this is especially the case where the water contains an excessive amount of iron or large numbers of organisms, as faucets are allowed to run for a long time in an attempt to make the water run clear. In the places represented in these diagrams water of poor

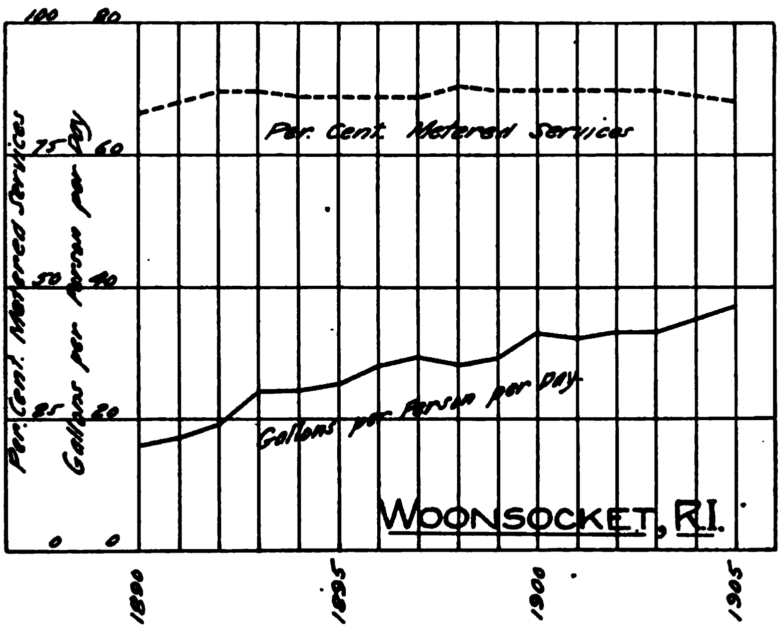


FIG. 5.

quality was supplied up to the time when the reduction in the consumption began. In the case of Reading the water contained such large quantities of iron as to make it practically unfit for any domestic purpose. After the construction of a filter to remove the iron the consumption of water was reduced very materially, and the greatest reduction occurred the year before the general introduction of meters. In Lowell and Lawrence meters were being rapidly introduced for many years before the reduction in

consumption began, and this reduction occurred immediately after the introduction of a better water supply.

It is very dangerous to draw conclusions from individual cases without a knowledge of all of the conditions, but the places in-

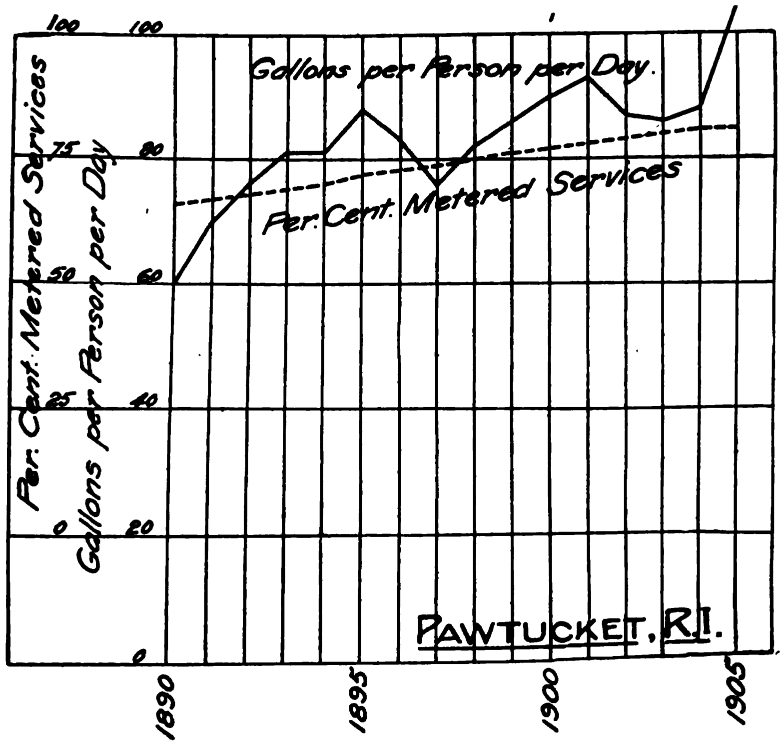


FIG. 6.

cluded in these diagrams are selected because they are typical of a large number of places.

Enough has been shown to indicate that the introduction of meters in places where the consumption of water has been large has not, in most cases, produced the results which have been anticipated. What, then, has been accomplished by meters, and what effect are they likely to have on the consumption of water in the future?

In the consideration of what meters will accomplish, it is convenient to divide the use and waste of water into the following classes:

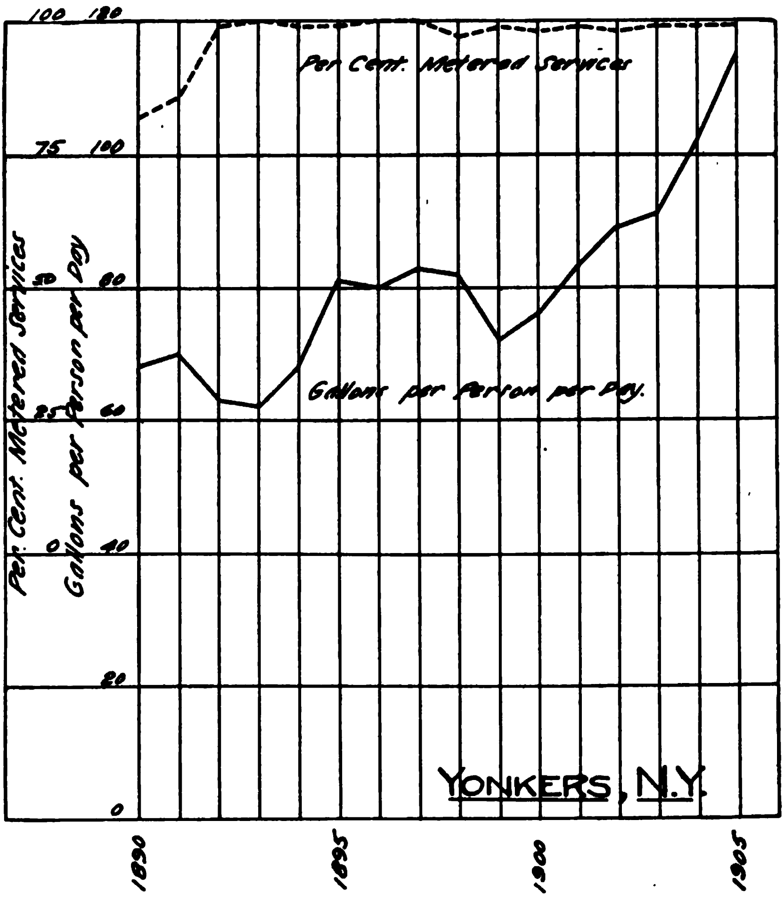
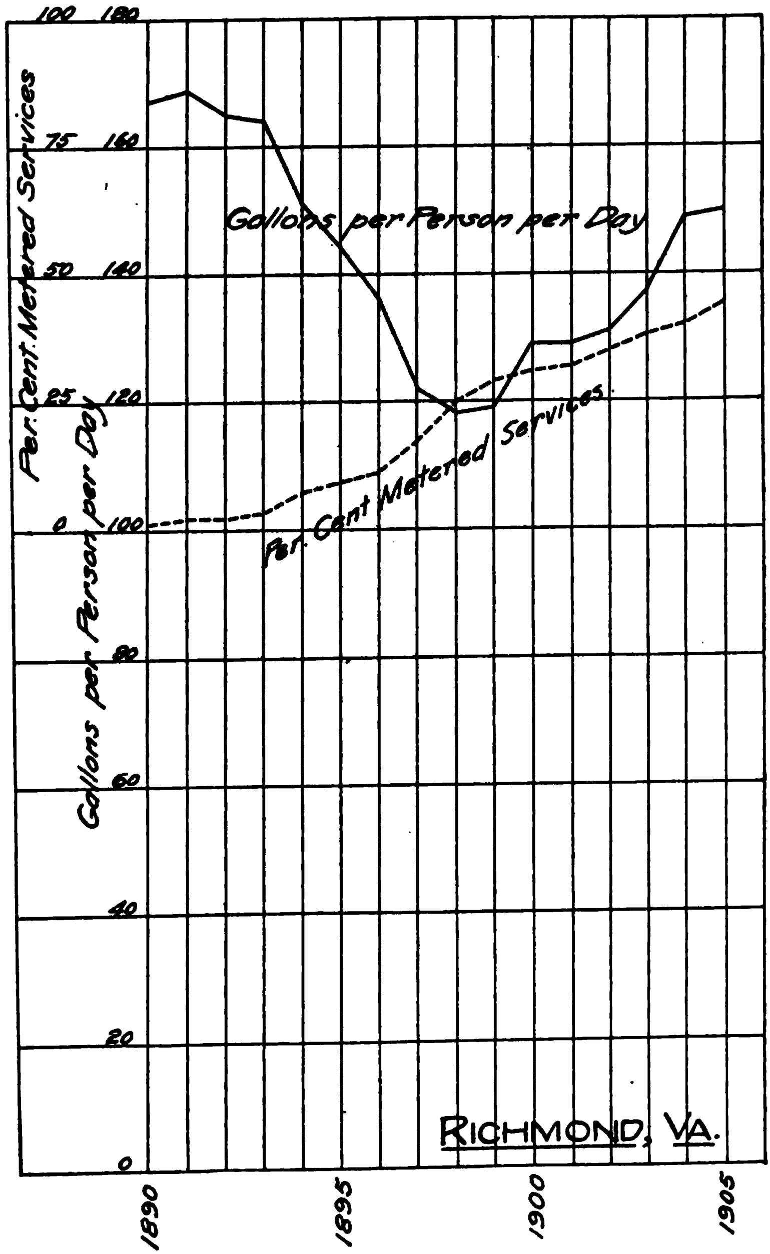


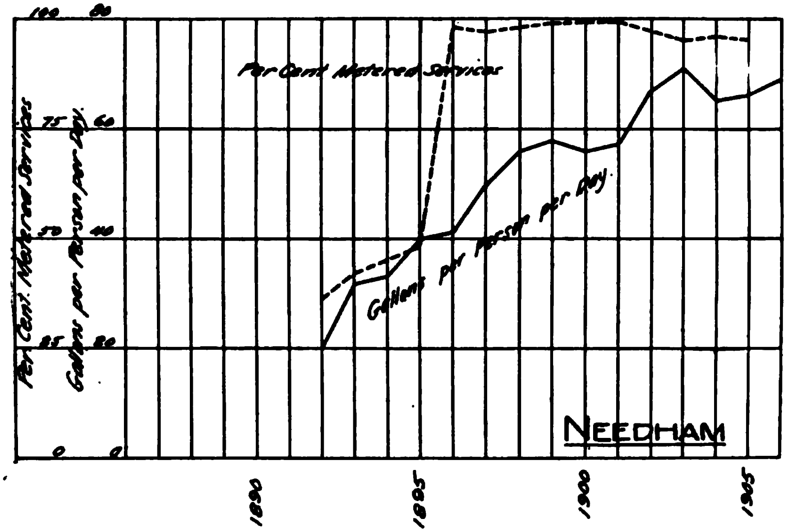
Fig. 7.

1. Water used or wasted in houses.
2. Water used in factories and for mechanical purposes.
3. Water used for public purposes, such as watering streets, supplying drinking fountains, etc.
4. Leakage from street mains, distributing reservoirs, and service pipes.



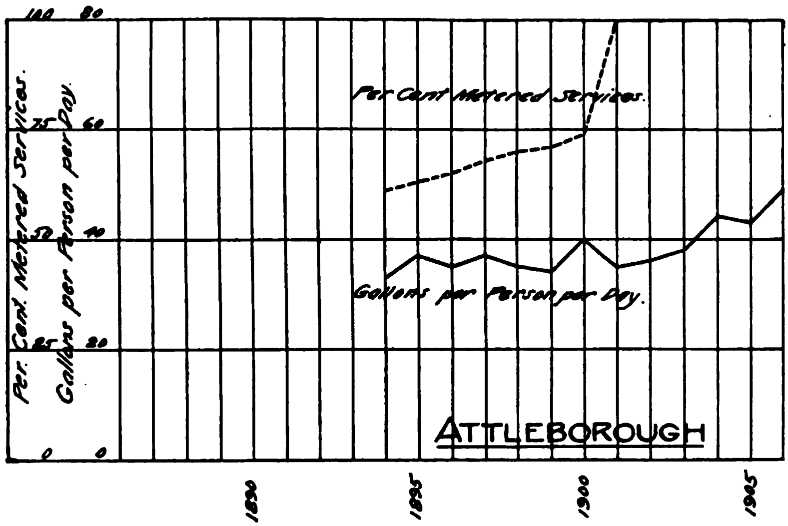
Gallons per Person per Day
Per Cent Metered Services
Per. Cent Metered Services
Gallons per Person per Day
100
75
50
25
0
180
160
140
120
100
80
60
40
20
0
1890
1895
1900
1905
RICHMOND, VA.

FIG. 8.



100 80
75 60
50 40
25 20
0 0
Per Cent. Metered Services
Gallons per Person per Day.
NEEDHAM
1890
1895
1900
1905

FIG. 9.



100 80
75 60
50 40
25 20
0 0
Per Cent. Metered Services.
Gallons per Person per Day.
ATTLEBOROUGH
1890
1895
1900
1905

FIG. 10.

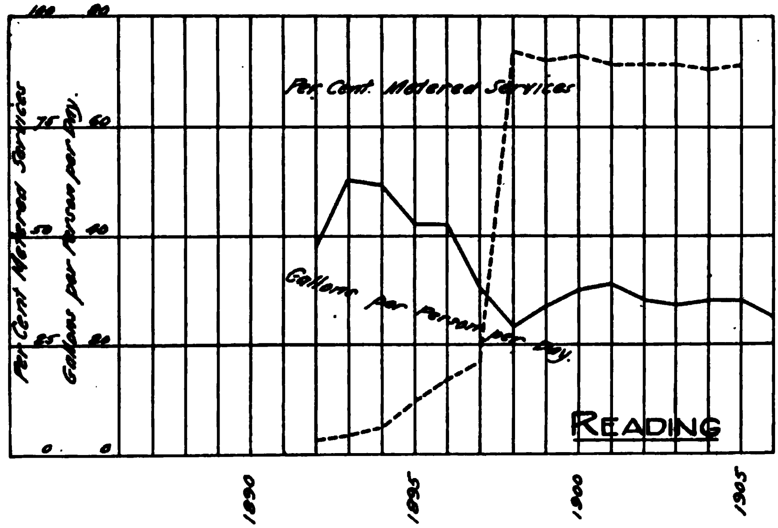

Per Cent. Metered Services
Gallons per Person per Day.
Per Cent. Metered Services
Gallons per Person per Day.
READING
100 80
75 60
50 40
25 20
0 0
1890
1895
1900
1905

FIG. 11.

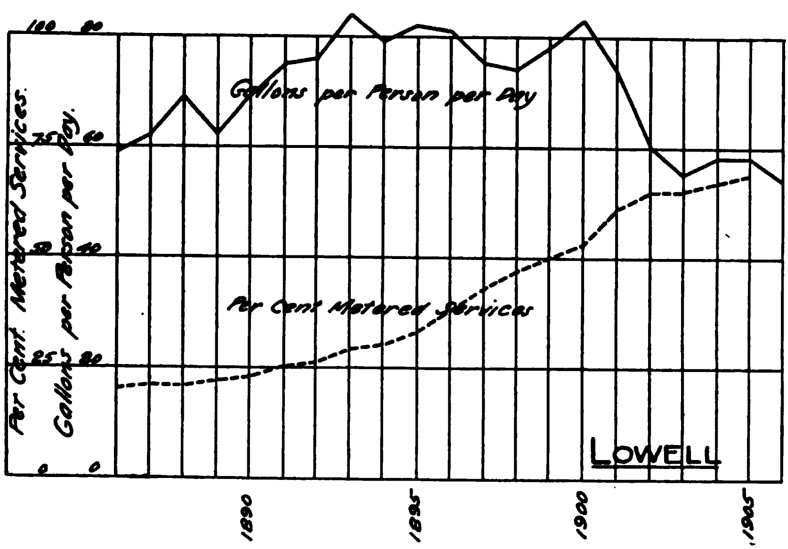

Gallons per Person per Day
Per Cent Metered Services
Per Cent. Metered Services.
Gallons per Person per Day.
LOWELL
100 80
75 60
50 40
25 20
0 0
1890
1895
1900
1905

FIG. 12.

The use and waste of water in houses includes water which leaks from defective pipes and fixtures or which is wasted by allowing the water to run continuously, and water which is intentionally drawn from the faucets or other fixtures. The quantity lost through defective plumbing fixtures is, in many cases, very large, and it is here that the house meter is most useful. Unfortunately, however, statistics in regard to the quantity actually lost cannot be obtained. Efficient inspection will do much toward preventing

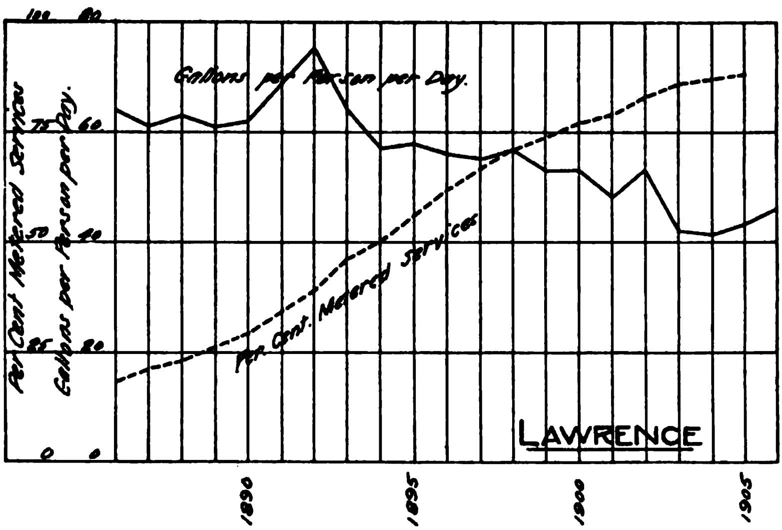


FIG. 13.

waste in this way, but increased water bills caused by leaky plumbing are more effective than the most efficient inspection.

The quantity of water wasted by intentionally leaving faucets open is probably much smaller than is generally believed. The line between the legitimate use and the waste of water is not well defined, but water which is intentionally drawn from the faucets or other fixtures, whether or not more than actually necessary for the purposes for which it is drawn, may be said to be legitimately used. Under this definition the water which is used by allowing the faucets to run during cold nights to prevent freezing may be

classed under legitimate use. Investigations have shown that the actual quantity of water consumed in this way is comparatively small.

The following table gives the relation which the consumption in each month bears to the average consumption, together with the average rainfall and temperature in Massachusetts:

TABLE No. 6.

PERCENTAGE WHICH THE CONSUMPTION DURING EACH MONTH IS OF THE AVERAGE MONTHLY CONSUMPTION, TOGETHER WITH THE AVERAGE RAINFALL AND TEMPERATURE. (MASSACHUSETTS.)

Average of Ten Years from 1896 to 1905.

Month.	Per Cent. of Average Consumption.	Rainfall. (Inches.)	Temperature. (Degrees F.)
January	90	3.68	23.9
February	92	3.98	24.3
March	89	4.77	34.9
April	87	3.86	45.6
May	100	3.18	57.2
June	113	3.60	64.5
July	124	3.85	70.7
August	118	3.97	67.6
September	108	4.12	61.4
October	96	3.35	50.9
November	90	3.34	38.7
December	92	3.74	27.7

It will be seen that the difference between the consumption during the coldest months and the consumption during April, — the month of minimum consumption, — is only 5 per cent. This excess of consumption generally comes in a few days, but it comes at a time when the sources of supply are least affected by a great draft upon them, except in cases where water is drawn from large storage reservoirs, and it comes at a time when the consumption is naturally small, so that the plant will not be called upon to do an excessive amount of work, as compared with the work required during the summer months. The cost of supplying the extra

water required to keep the faucets from freezing is insignificant as compared with the cost of repairing frozen pipes, and while I would not advocate putting plumbing in a house in such a manner that it would be necessary to allow the water to run during cold weather, I cannot criticise very severely the householder who uses a few cents worth of water to save a plumber's bill of many dollars, and if the water is sold at meter rates such use of the water is certainly legitimate. The quantity of water used for this purpose is undoubtedly greater than is necessary, and is reduced by the introduction of meters, but the total saving is in most cases an exceedingly small proportion of the yearly consumption.

The quantity of water actually used for strictly domestic purposes is increasing at a very rapid rate. In the first place, the number of fixtures in houses is increasing. This is especially noticeable in the less expensive houses, which now contain many plumbing fixtures where formerly a single faucet was all that would be provided. Not only is the number of fixtures increasing rapidly, but the quantity of water used by each fixture is increasing. The modern sinks, water-closets, and bath-tubs require very large quantities of water. The faucets and pipes are made of such a size that they deliver water much more freely, which tends to increase the quantity used. In the State House at Boston the water-closets are so constructed that every time a closet is flushed 5 gallons of water enter the sewer. The wash-basins are of such a shape and size that in order to obtain a sufficient depth of water for washing the hands it is necessary to draw from 1½ to 2 gallons, and the basins hold 2½ gallons when full to the overflow. It is easy to figure that a person of ordinary cleanliness, with such plumbing fixtures as those in the State House, and with a modern large-sized bath-tub, will use a much larger quantity of water than that allowed the average person in many of the estimates which are made of the quantity of water necessary for a water supply. The American people are undoubtedly wasteful, not only of water, but of all other commodities, and it is safe to say that they will not submit to being restricted in the use of water for which they are willing to pay any more than in the use of food supply or of fuel, of which large quantities are wasted.

Many interesting facts have been published from time to time

in regard to the actual consumption of water in houses of different classes, as indicated by meter readings. Table No. 7 gives a summary of recent studies made in Fall River, — a manufacturing city where the consumption is 42 gallons per person per day, — and in Needham,— a residential town where the consumption is 79 gallons per day. Meters are very generally used in both places.

TABLE No. 7.

STATISTICS IN REGARD TO THE CONSUMPTION OF WATER IN HOUSES OF DIFFERENT CLASSES IN FALL RIVER AND NEEDHAM, MASS.

(FALL RIVER.)

Class.	Number of Persons.	Gallons per Person per Day.	Persons per Water-Closet.	Persons per Bath-Tub.
A	44	49.6	1.6	2.6
B	160	23.7	2.5	4.3
C	550	13.2	3.9	8.3
D	792	12.2	7.6	*

(NEEDHAM.)

Class.	Number of Persons.	Gallons per Person per Day.	Persons per Water-Closet.	Persons per Bath-Tub.
A	68	71	3	3
B	73	20	5	5
C	131	9	9	10

* No bath-tubs.

In each case class A represents the most expensive houses, surrounded by lawns, and the last class includes some of the cheapest tenement houses. . When it is considered that a large proportion of the houses in Fall River would be included in the last classes, while a comparatively small proportion is included in the last class in Needham, a portion of the difference in the consumption of water in these two places is accounted for.

To further illustrate the difference in the consumption of water in different classes of cities or towns, Table No. 8, which gives the average consumption of water in the cities and towns of Massachusetts, arranged in groups, is introduced.

TABLE No. 8.

AVERAGE CONSUMPTION OF WATER DURING EACH MONTH IN 1905 IN CITIES AND TOWNS ARRANGED IN GROUPS.

(Gallons per Person per Day.)

Month.	Boston.	Metropolitan District.	Average of 23 Suburban Cities and Towns.	Average of 14 Large Manufacturing Cities.	Average of 37 Small Cities and Towns.	Average of 12 Summer Resorts.
January ..	165	137	77	70	48	67
February .	175	147	85	74	53	75
March	152	127	77	69	50	65
April	140	117	73	65	46	65
May	144	121	79	68	52	89
June	146	123	79	70	53	109
July	151	131	88	72	58	150
August ...	148	127	79	69	56	131
September	147	126	75	65	50	101
October...	145	124	73	65	47	74
November.	144	122	70	64	46	61
December .	153	129	71	64	45	65
Year	151	128	77	68	50	88

This table shows not only the difference in the average consumption for the year in the different classes of cities and towns, but it shows the monthly differences in the use of water. In the case of the summer resorts, the summer consumption is large for obvious reasons. In the suburban places there is a great quantity of water used on lawns and gardens, which increases the summer consumption.

These tables serve to show that there are natural differences in the use of water which cannot be overcome by the introduction of meters, and that it is impossible to produce, in places like Needham, conditions like those in Fall River.

The quantity of water used in manufacturing differs greatly in different places, due to differences in the character and location of the town, the character of the factories, and the attitude which the town takes in regard to supplying water to the factories. The quantity used in factories for sinks and water-closets has been determined from a study of the meter readings in a large number

of factories in various cities, and is found to be fairly uniform in places where water used for this purpose is metered. Table No. 9 gives characteristic results from several factories examined.

TABLE No. 9.

WATER USED FOR SINKS AND WATER-CLOSETS IN FACTORIES WHERE ALL WATER IS METERED.

Number of Operatives.		Water Used. Gallons per Day per Operative.
600		2.3
2 093		5.9
100		3.6
1 500		3.1
270		6.1
50		3.2
275		5.4
400		2.3
220		5.9
120		2.1
1 000		5.6
545		2.9
769		2.2
609		3.6
50		6.1
150		4.3
525		6.6
510		3.0
130		4.0
125		2.8
	Average,	4.0

The figures in the above table are for factories where the water used is paid for by measurement. The quantity used in many factories where the water is not measured is very much in excess of these amounts, as the water is often allowed to run continuously through both sinks and water-closets.

The quantity of water used in manufacturing processes or for mechanical purposes is frequently large in comparison with the quantity used for strictly domestic purposes, and in some places the use of water by factories is encouraged by making only nominal charges for it, the smaller consumers being in such cases taxed for the support of the factories. There is now being constructed

for a New England city an expensive plant for the purification of 300 gallons per person per day, a large proportion of this water going to the numerous factories located in the city, but the city officials in this case prefer to incur the expense of a large purification plant rather than curtail the use of water in the factories.

In some cases factories are so situated that an independent water supply cannot be obtained, and it is necessary to obtain water from the public works. The quantity used in manufacturing processes can be ascertained only by investigation in each particular case, and before attempting to prophesy what can be done by domestic meters in any town, it is necessary to know how much water is used by factories and for mechanical purposes.

Table No. 10 contains interesting statistics in regard to the largest metered consumers of water in various cities and towns.

TABLE No. 10.

USE OF WATER BY LARGEST CONSUMERS.

City or Town. (Massachusetts.)	Average Daily Consumption.		Quantity Used by Ten Largest Consumers.		
	Gallons per Day.	Gallons per Person per Day.	Gallons per Day.	Gallons per Person per Day.	Per Cent. of Total Consumption.
Andover	484 000	73	61 800	9	12.8
Attleboro	641 000	49	62 100	5	9.7
Brockton	1 993 000	40	166 100	3	8.3
Clinton	543 000	42	146 100	11	26.9
Fall River ...	4 478 000	42	444 300	4	9.9
Lawrence	3 308 000	46	335 800	5	10.2
Lowell	5 084 000	54	189 900	2	3.7
Malden	2 000 000	51	113 100	3	5.7
Marlboro	554 000	39	98 600	7	17.8
Middleboro	263 000	38	77 000	11	29.0
Newton	2 223 000	59	115 100	3	5.2
North Andover	202 000	43	27 400	6	13.6
North Attleboro	282 000	35	15 000	2	5.3
Norwood	403 000	58	108 600*	16*	26.9*
Reading	147 000	25	7 300	1	5.0
Taunton	1 915 000	62	388 900	13	20.3
Watertown ...	771 000	67	134 700	12	17.5
Wellesley	273 000	43	24 300	4	8.9
Worcester	9 193 000	71	1 511 700	12	16.4

* Eight largest consumers.

The quantity used by ten of the largest consumers of water is given, together with the increase in the average per capita consumption due to these ten consumers. Upon studying this table some of the inequalities in the figures in consumption are explained. If the amount consumed by the ten largest consumers is deducted from the total consumption, the amount used by the remaining consumers in the different cities and towns is much more uniform. If 20 consumers had been included there would be a still greater similarity in the quantity used by the remaining consumers. It will be seen that in those places which have been so frequently referred to, namely Brockton and Fall River, there are no very large consumers of water. In Brockton the shoe shops use but little water, and in Fall River the water used by the factories is obtained from independent sources. In places having a large per capita consumption of water, the amount used by the large consumers is a very substantial proportion of the total consumption. In all of the places included in the table water is paid for at meter rates, and it is evident that the further introduction of meters in places like Norwood, Taunton, and Watertown is not likely to reduce the consumption to that of North Attleboro and Reading.

Very little is known about the quantity of water used for public purposes. Even where practically all of the domestic services are metered, it is not common to measure the quantity of water used for street watering, supplying drinking fountains, and other similar purposes. The quantity used for such purposes is undoubtedly very large, and in many places unnecessarily large, but in general the quantity so used will not be affected by the general use of meters. Statistics obtained from several places in Massachusetts indicate that the quantity used for such purposes amounts to from 4 to 10 gallons per person per day.

The quantity of water lost by leakage from street mains, distributing reservoirs, service pipes, etc., is in many cases very excessive. The best estimate of this quantity is obtained from a comparison of the quantity of water drawn from the sources of supply with the quantity of water passed through meters in those places where practically all of the services are supplied with meters. Statistics for a number of places where records of this kind are available are given in Table No. 11.

TABLE No. 11.

TABLE SHOWING THE RELATION BETWEEN THE QUANTITY OF WATER PASSED THROUGH METERS AND THE TOTAL QUANTITY OF WATER PUMPED IN 1905 IN CERTAIN CITIES AND TOWNS IN WHICH THE SERVICES ARE LARGELY PROVIDED WITH METERS.

City or Town (in Massachusetts when not otherwise indicated).	Per Cent. of Metered Services.	Total Quantity of Water Pumped in 1905. (Gallons.)	Quantity Passed through Meters. (Gallons.)	Per Cent. Passed through Meters.
Attleboro	100	200 753 000	94 728 000	47
North Attleboro	100	150 473 000	51 948 000	45
Wellesley	100	105 503 000	55 014 000	52
Ware	100	128 539 000	84 121 000	65
Yonkers, N. Y.	99	2 334 459 000	1 100 884 000	47
Fall River	97	1 608 652 000	956 168 000	59
Winchendon	97	35 446 000	16 154 000	45
Madison, Wis.	97	537 187 000	165 951 000	31
Needham	95	103 487 000	26 012 000	25
Worcester	95	3 517 397 000	1 881 254 000	53
Watertown	94	287 605 000	153 676 000	53
Brockton	90	732 083 000	416 188 000	57
Lawrence	88	1 094 881 000	570 736 000	52
Clinton	86	197 938 000	104 277 000	53
Newton	86	785 222 000	510 000 000	65
Burlington, Vt.	79	385 443 000	208 139 000	54
Andover	78	164 151 000	54 423 000	33
Malden	78	737 127 000	289 262 000	39
North Andover	74	72 170 000	23 557 000	33
Lowell	69	1 998 929 000	801 401 000	40
Cleveland, Ohio	68	22 053 442 000	10 780 154 000	49

It will be seen from this table that practically half of the water which is drawn from the sources is unaccounted for by the meters. This discrepancy is doubtless due in part to errors in the registration of the meters and in part to errors in the rating of the pumps where the quantity drawn from the sources is determined by the pumping records. There is also, in many of these places, a large quantity of water which is used for street sprinkling and for drinking fountains and similar public uses which is not measured, but after allowance has been made for all of these errors and uses there still remains a large quantity of water which is not accounted for which must be attributed to leakage in the system. To whatever this discrepancy between the quantity drawn from the sources

and the quantity actually used is due, — whether to the use of the water in the streets or to leakage, — it is evident that it is not affected by the use of meters. The quantity thus unaccounted for in the places included in the table amounts to a per capita consumption of from 14 to 70 gallons per day.

In practically all of the places included in the foregoing tables the water supply is obtained by pumping, as it is, unfortunately, only in such places, as a rule, that any knowledge can be obtained as to the quantity of water used. In only a few cases where water is supplied by gravity are there any means of measuring the water, and it is safe to say that the consumption, in places where nothing is known of the quantity of water consumed, is much greater than in those places where such records are kept. It is undoubtedly a fact that in some cases almost as much would be accomplished by the introduction of large meters on the main lines of supply as by the introduction of house meters. In this connection I can do no better than to quote from a statement made in 1900 by Mr. X. H. Goodnough, chief engineer of the Massachusetts State Board of Health:

"In cases where water is supplied by gravity it is generally considered unnecessary and often a waste of money to attempt to make any continuous and approximately correct record of the quantity of water used. There is no doubt, however, that in many such cases a knowledge of the excessive use of water would lead to a great reduction in waste and to a saving in the cost of construction and operation of the works far greater than the expense of making the necessary measurements."

A good illustration of the value of a knowledge of the quantity of water used is found in the experience of the city of Holyoke, where meters were recently introduced on the main lines of supply. It was found upon reading these meters that the average daily consumption of water in the city was 144 gallons per person. Upon making this discovery steps were immediately taken to ascertain where the water was going, and by vigilant inspection during a period of a few months the consumption was reduced to 103 gallons per day, the actual saving of water amounting to over 2 000 000 gallons per day. During the investigations which were made it was found that large quantities of water were being

stolen, and it is said that the revenue has been increased very materially by these discoveries, directly attributable to the introduction of large meters on the supply lines.

From a consideration of the foregoing facts it is evident that disappointment is inevitable in the case of many cities and towns where meters are being introduced. In the case of one town which has recently come to my notice, the population is about 10 000 and the per capita consumption is from 96 gallons per day in winter to 128 gallons per day in summer, and the general introduction of meters has been recommended to obviate the necessity of obtaining an additional supply. In this town one factory uses 200 000 gallons of water per day, — amounting to 20 gallons per person per day, — the water being furnished under a fifty-year contract, the town to receive one-half cent per thousand gallons. There are other factories in the town which are supplied with unknown but probably smaller amounts of water. The town uses cement-lined, wrought-iron mains, which are laid in a sandy soil where leaks of considerable size would remain undetected for a long time. There is also a very large summer population, which increases the draft during the summer months. While the general introduction of meters in this town would undoubtedly result in a saving of water, and should be unhesitatingly recommended, it is certain that results like those obtained in the cities of Brockton, Fall River, and Providence are not possible, and it is doubtful if the consumption in this particular town can be reduced to less than from 80 to 90 gallons per person per day, without restricting the use of water in the factories.

I do not wish to be understood to question in the least the advantages of selling water by measurement. I am convinced that it is the only proper method of selling water, and that it should become universal. Neither do I question that a great saving in the use of water can be made by the introduction of meters. The most recent experience, however, shows conclusively that the extravagant claims which have been made as to the reduction in the quantity of water made possible by the introduction of meters are not fulfilled, and I have endeavored to show by an analysis of the figures some of the reasons why the predicted results have not been accomplished, and why they are not likely

to be accomplished with the present tendency toward a greater use of water for almost every purpose. I have also endeavored to show that a prediction as to what meters will accomplish in any particular case should not be made without some knowledge of the principal sources of use and waste, to determine how much of the consumption is susceptible of regulation by meters.

DISCUSSION.

President John C. Whitney. Gentlemen, the paper is now open for discussion. There is an opportunity for the gentlemen representing the communities referred to by Mr. Johnson to explain why it is that meters have not restricted the consumption of water in certain places.

Mr. George A. King.* Mr. President, there is one point which, it seems to me, bears on this question that Mr. Johnson has not touched upon, and that is the care of the meters. I noticed that in a great many of the cases quoted the consumption decreases for five or six years, and that it then begins to increase. With the little experience that I have had, I have noticed that after four or five years the meters do not do their duty, and they should be taken out, cleaned, and repaired, and that then they will register as they should. If an increased consumption is not followed by an increased bill, the consumption will further increase. The increased consumption may not be shown by the meter because it is more or less out of order. I think that this may account for some of the increases in consumption based on the pump records. I have one case in mind where I took out a meter on which there were four tenements. Those four tenements had not been consuming 40 000 gallons a year, according to the meter. For the first year, or a little over ten months, I think, after the meter was changed, the bill increased from $10 to $25, and last year the bill was over $30. I think that the lack of care of meters may account for some of the difference which Mr. Johnson shows.

The President. I wonder if Mr. Johnson has taken into account, in making up his figures, the date of the introduction of sewers into these various towns?

Mr. Johnson. I gathered together some figures to show the

* Superintendent of Water Works, Taunton, Mass.

effect of the introduction of sewers on the consumption of water, but the information was so meager that I did not care to present it. I found that the average consumption for the year previous to the introduction of sewers in six cities and towns was 42 gallons per person per day. In the same cities the year after the completion of the sewerage system the consumption was 48 gallons per person per day. The increase in the consumption in seven years previous to the construction of the system was 9 gallons per person per day, and in the six years after the completion of the system the increase was 13 gallons per person per day.

Mr. Charles W. Sherman.* There is one other point which Mr. Johnson has not touched on, and which might in the case of some of the smaller cities and towns have some effect on the figures of per capita use of water, where the figures presented are based on total population, and that is a gradual extension of the water system to include a larger portion of the town. In the case of small towns especially there are often outlying districts of considerable extent which are not reached by the water system, and if the total population of the town is taken in figuring the consumption, the result would naturally be materially different from the consumption per person actually supplied. As the works gradually extend to the outlying districts the per capita consumption would tend to a larger figure, even though the actual consumption or use of water per consumer remained unchanged. That consideration should be borne in mind in considering the smaller places; probably in the larger it would have no appreciable effect. Referring to the question of water unaccounted for, I am somewhat familiar with the records of a small water company in Iowa, where the policy of metering every service was adopted about three years ago. The main pipe system was constructed ten or eleven years ago, and it has not, of course, been possible to overhaul that. The best estimates possible of the amount of water used for street watering and for any other unmetered use of water, as at fires, — which represent comparatively small quantities, as the town is not a large one, — are made, and a reasonable allowance made for slip of the pumps; and upon that basis the quarterly records of the water pumped, as compared

* Civil Engineer, Boston, Mass.

with the quarterly meter readings, shows the amount unaccounted for to be about 33 per cent. of the total water pumped. The mains have been carefully examined so far as possible, and the whole system has been examined for leaks back of the meters. Some were discovered in the first examination, but not enough to make an appreciable effect on the percentage unaccounted for. In making the investigation, we found what perhaps many of the members may not be familiar with, — a little instrument known as the phonendoscope, once used by physicians, which is practically a type of stethoscope, in which the diaphragm has a little metallic or hard rubber rod extending from it. This can be put against a gate valve in listening for leaks, and the ear tubes, as in the ordinary stethoscope, concentrate the sounds very nicely. The whole instrument is contained in a little nickeled box about 3 inches in diameter and an inch and a half thick. It is a very valuable instrument for such purposes.

MR. WALTER H. RICHARDS.* Mr. President, in this connection I should like to refer to an incident that has just come to my notice. A superintendent of water works in a small town referred to me to see if I could help him out of this difficulty: He had a new meter on some buildings which had been in use about a year, and he was not satisfied with the registration, so he put on a second meter, on the same line of pipe, and after taking the registration for a month or two, he found that it registered 39 per cent. less than the first meter. That did not satisfy him, so he put on another meter, and after running a month or two, that registered about 35 per cent. more than the second meter and 9 per cent. less than the first one. As he had no meter tester, he sent them on to me to test. I tested them and found them all practically correct, every meter, from my testing. There was considerable sediment, iron rust, came out of the meters when we blew them off, as we have to do before testing them.

Regarding the showing of the tables presented to-day, while they show an apparently increased consumption per capita with the introduction of meters, this increase is not necessarily waste, and as a matter of fact the waste may be, and probably is, reduced, the increase being due rather to the increased use of water-closets,

* Superintendent of Water Works, New London, Conn.

baths, or other sanitary fixtures made possible by an extension of the sewer system; and even the establishment of a large factory might increase the per capita consumption. That the per capita consumption increases and is increasing for local special reasons is undoubtedly true, and that the introduction of meters decreases the waste is equally true and proven.

The tables illustrate the fallacy of drawing conclusions from statistics when some of the factors are omitted.

MR. JOHN F. J. MULHALL.* Mr. President, there was one question overlooked in Mr. Johnson's paper; that is, in reference to slip of pumps. In Mr. Wheeler's companies, — he and his associates operate about twelve, — we keep daily records of the pumpage, and make an average per year of the annual consumption in Massachusetts. The average per capita per year seemed to us so enormous that we made an investigation and found that the pumps showed a slip of between 20 and 30 per cent.,— between 40 and 50 per cent. on one pump. I understand that Mr. Johnson has given figures computed on the displacement of the pumps, and that would account, in some cases, — in fact, I think in the great majority of cases, — for the great percentage of unaccounted for water, in addition to the leaks in the system.

MR. DEXTER BRACKETT.† Mr. Johnson's paper is a very valuable contribution to the literature on this most important subject, and I am pleased to note that he believes that the only proper method of selling water is by measurement. It must not be expected, however, that the measurement of water supplied to individual water takers will prevent leakage and waste from the street mains. What is required in order to obtain the best results is a complete system of measurement of all the water used, not only that used and wasted by the individual water takers, but also that wasted from street mains as well. If, with a system having 95 per cent. of the services metered, only 25 per cent. of the quantity supplied is accounted for by the meters, it can safely be assumed that there is a large leakage from the street mains, which should be prevented. By supplying sections of a distributing system through large meters, leaks from the distributing

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* Water Works Accountant, Boston, Mass.

† Chief Engineer Metropolitan Water Works, Boston, Mass.

pipes can often be located, and the stopping of a few of these leaks often results in the saving of a large amount of water.

I think the writer has underestimated the quantity of water which is wasted from faucets intentionally left open, and I cannot agree with the opinion that all water which is intentionally drawn from water fixtures may be considered as legitimately used, including water allowed to run to prevent freezing of services. As an illustration of the quantity used for this purpose, the following examples taken from records of the Metropolitan works may be mentioned. The average per capita consumption in the city of Chelsea during the months of December, January, February, and March for the past three years has been respectively 55, 52, and 41 gallons greater than the average for the months of November and April. As the only cause for increased use during the winter months is the waste to prevent freezing of services, it follows that the average family of five persons in the city of Chelsea uses yearly about 30 000 gallons of water for this purpose, which, at the usual meter rate of 30 cents per 1 000 gallons, has a value of $9. The actual quantity used by those who follow this practice is much greater because not all the water takers find it necessary.

The city of Boston used about 30 gallons more per capita during the months of December, January, February, and March than during the months of November and April, indicating a use or waste of 10 gallons per inhabitant, or 6 000 000 gallons per day *for the whole year*, for preventing the freezing of services, — a quantity which can hardly be considered insignificant.

Doubtless a few water takers will use some water for this purpose even if supplied by meter, but in places where meters are in general use the increase in the quantity used during cold weather is comparatively small. In Belmont, Malden, Milton, and Watertown, where practically all the services are metered, the per capita consumption during the winter months of 1906 and 1907, as compared with that of the months of November, 1906, and April, 1907, was as follows:

	Average Nov. and April (Gallons).	Average Four Winter Months (Gallons).
Belmont	54.5	57
Malden	47.5	49
Milton	42.0	41
Watertown	66.0	60

It cannot be expected that the per capita consumption in cities which have a large transient population, or where there is a large use of water for business and manufacturing purposes, can be reduced by the use of meters to 50 gallons, and in some cases probably not below 150 or 200 gallons; but the experience of the cities and towns of New England where water is paid for in proportion to the quantity used proves that in places having a population of less than 50 000 the average per capita consumption should not exceed 50 gallons unless the manufacturing use is disproportionately large. On the other hand, in a city like Buffalo, N. Y., where the cost of water is small, and where the 2 per cent. of the water takers who are supplied through meters use a quantity equivalent to 46 gallons for each inhabitant of the city, the universal use of meters would probably not reduce the per capita consumption below 150 or 200 gallons.

During the past twenty years there has been a great increase in the number of water fixtures per capita, an increase in the quantity of water required per fixture, and a tendency toward an increase in the pressure furnished, all of which tend toward an increase in the use of water. So long as the water is paid for at schedule (fixture) rates the water taker has little interest in the quantity used, but with the general use of meters more attention will probably be given to the determination of the number and size of fixtures required to give the best results, as in the case of lighting at the present time, where attention is now given to the question of obtaining the burners which give the best results with the least expenditure of gas and electricity.

The quantity of water used in the eighteen municipalities supplied by the Metropolitan works is now measured by Venturi meters, and figures showing the per capita use of water in these municipalities may be of interest in the study of this subject. Table No. 12 gives the per capita consumption, as well as the population and percentage of services metered in the different cities and towns supplied by the Metropolitan works for the year 1906:

TABLE No. 12.

POPULATION, PERCENTAGE OF SERVICES METERED, AND CONSUMPTION OF WATER IN THE MUNICIPALITIES OF THE MASSACHUSETTS METROPOLITAN WATER DISTRICT. 1906.

City or Town.	Population. 1906.	Per Cent. of Services Metered.	PER CAPITA CONSUMPTION. (Gallons.)												
			January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Av. for Year.
Boston	601 430	5	158	162	154	146	149	151	148	149	149	143	141	165	151
Somerville	70 950	19	88	88	83	81	90	93	92	94	92	89	84	92	89
Malden	39 040	78	51	50	49	50	52	54	55	53	54	48	48	49	51
Chelsea	38 000	10	102	117	106	92	89	92	93	97	97	87	83	113	97
Everett	30 270	2	83	91	84	78	80	83	80	82	80	74	69	87	81
Quincy	28 300	3	105	107	108	103	112	117	109	113	115	99	95	97	107
Medford	20 080	8	91	94	90	90	104	105	103	108	117	104	96	101	100
Melrose	14 650	3	112	111	109	111	113	106	108	110	113	107	101	106	109
Revere	13 390	4	67	74	73	66	80	97	99	104	93	73	68	85	82
Watertown	11 550	93	60	59	60	64	73	74	70	69	71	71	69	61	67
Arlington	9 940	22	70	75	72	72	88	90	83	87	94	82	76	76	81
Milton	7 120	100	36	35	39	42	62	64	56	61	61	47	43	44	49
Winthrop	7 240	2	98	104	98	96	106	127	135	145	131	107	98	110	113
Stoneham	6 350	2	62	63	59	62	67	69	69	76	84	78	72	71	69
Belmont	4 410	100	38	38	45	54	76	77	71	76	92	65	52	56	62
Lexington	4 230	2	57	60	62	74	97	101	96	98	92	79	68	66	79
Nahant	1 850	18	62	68	62	68	69	74	68	80	82	48	74	85	71
Swampscott	6 240	0	87	75	68	71	74	78	87	96	88	68	76	66	79
Metrop'lit'n Distr't,	915 040	12	132	136	129	123	128	130	127	129	129	122	119	138	128

MR. ROBERT J. THOMAS.* Mr. President, I noticed in Mr. Johnson's paper that Lowell was an exception to the rule, and doesn't quite coincide with his conclusion as to the increased consumption of water after meters were placed. According to his diagram and the figures for 1906 in my possession, the consumption of water in Lowell for 1906 was the lowest it has been for seventeen years.

This decrease in consumption is due, unquestionably, to the use of meters. For a number of years the city of Lowell put on meters as the consumers of water applied for them, and those applying for meters generally were people who built good houses to live in themselves and were satisfied that they would save money by meters. In other words, the placing of meters was optional. Consequently that didn't affect the consumption of water greatly. But in 1900, several years after driven-well water was introduced, the water board applied meters to a thousand services where they believed, from the reports of their inspectors, that water was being wasted. The effect was almost immediate — within the year. A decrease of consumption took place, and ever since this compulsory placing of meters on all new services has carried that same result along with it. The reduction in the consumption of water began in 1900; and the consumption has been working down, so that last year, 1906, it was the lowest for seventeen years, due undoubtedly to the enforcement of the meter system and the placing of a thousand meters on the most wasteful services.

As to the matter of the improvement in the quality of the supply having anything to do with it, I doubt very much the effect of that, because, as I said, although the new water supply was introduced in 1896, — that is, the well systems were built then, — it was since then that this great decrease in the consumption took place.

Now, Mr. Johnson speaks of Yonkers and the great increase of the consumption of water there. I know for a fact that in Yonkers they improved the water supply recently. They put in driven wells and they filter their water, so that ought to decrease the consumption as it did in Lowell, instead of increasing it.

In regard to the assumption that letting water run in winter season to keep it from freezing is legitimate, I take issue with Mr. Johnson. I think a house where the water pipes will freeze is not a fit habitation for a human being.

* Superintendent of Water Works, Lowell, Mass.

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The average daily consumption in Lowell last year was about 5 000 000 gallons, with a population of about 100 000 people. If we had not applied meters our consumption would be nearly three times as much, and if it were, we would have to use Merrimac River water to-day, because the quantity of well water would not be sufficient to supply such extravagant and excessive use of water. And that would mean a very serious proposition for the city of Lowell. In 1890 Lowell had over 496 cases of typhoid fever and 124 deaths when using Merrimac River water. Last year, using well water, there were 7 deaths from typhoid fever, with about 27 cases. That speaks for itself. That is an argument in favor of meters very convincing to me.

MR. FRANK L. FULLER.* Mr. President, I want to second what has been said in regard to the value of the paper which Mr. Johnson has presented to us. I know from experience in investigating such subjects that he must have put a large amount of work into it, and I think he deserves much credit for what he has done.

Just before coming to this meeting I received the proof of a diagram which has been prepared for the Wellesley water report for 1906 (Plate I). This diagram is instructive and throws light on the question of the introduction of meters.

The Wellesley works were built in 1884, and the use of water commenced the following year. Almost immediately the use of meters began in a small way. Their use was not compulsory, but water takers were allowed to install them, and a rate for metered water was established.

The amount of water pumped increased very rapidly. For instance, in 1886, with 1 058 consumers, the average pumpage was about 2 700 000 gallons per month, and this increased until, in the year 1890, with 2 650 consumers, the pumpage was a little less than eight million gallons per month.

At the close of the year 1892 there were 164 meters in use. The next year (1893) 402 meters were added, and at the close of that season 566 were in use. The number of service taps at the close of 1893 was 610, which indicates that meters had been placed on nearly all services.

The 402 meters mentioned above is the largest number of meters installed, or likely to be installed, in any one year.

* Civil Engineer, Boston, Mass., and member of Water Board, Wellesley, Mass.

As soon as nearly all consumers used water through meters, the pumpage of water began to decrease. By an examination of the diagram it will be seen that the amount of water pumped in 1890 was about the same as in 1902, or twelve years later, while the number of consumers had increased from 2 650 to 5 147, or had nearly doubled.

I do not know what the condition of the Wellesley water supply would have been at the present time if meters had not been introduced. Before meters began to be generally used, the pumpage practically doubled every second year. The town would have been compelled to go outside of its own limits to secure a new supply, or would have been driven to the expensive expedient of installing a plant for the filtration of the water of Rosemary Brook or Charles River. With all consumers metered, the town of Wellesley now has a sufficient supply for some years to come.

The following table is obtained by dividing the total pumpage for each year (obtained from the plunger displacement) by the number of consumers for that year. It, of course, includes water used for sprinkling streets and lawns and the small amount used in extinguishing fires and flushing pipes. It is somewhat too large on account of insufficient allowance for slip of the pump, which was corrected for the year 1906. The pumping engine is of the duplex pattern, made by the Geo. F. Blake Manufacturing Company in 1884, and has a capacity of 1 000 000 gallons in twenty-four hours.

Year.	Daily Supply of Water per Consumer. Gallons.	Year.	Daily Supply of Water per Consumer. Gallons.
1885	64	1896	62
1886	84	1897	55
1887	67	1898	43
1888	77	1899	51
1889	79	1900	48
1890	97	1901	48
1891	91	1902	50
1892	84	1903	55
1893	69	1904	55
1894	63	1905	59
1895	58	1906	54

I should like to emphasize what has been said in regard to the importance of knowing the exact amount of slip to be allowed

for when pump records are used in determining the amount of water pumped during the year. The Wellesley pump was tested last year and the slip found to be about 11 per cent. An allowance had previously been made, but probably not enough. All pumping engines should be tested for capacity as often as practicable,—at least once in two years,—if fairly accurate results are to be expected. It is probable that most pumps are not delivering the amount of water with which they are credited. In towns where the entire consumption is metered, a portion (it may be small) of the great discrepancy between the pump and meter records may be due to overrating the capacity of the pump.

Dividing the total amount of water passed through meters in Wellesley by the number of consumers, we have as the average daily amount of water *used* by each consumer, 33 gallons. The difference between this amount and the 54 gallons obtained from the pump record is 21 gallons per consumer, which is lost in various ways.

In order to locate this loss, our superintendent made a careful test of our 600 000-gallon covered reservoir (the one ordinarily used) for twenty-three hours and found it practically tight. We have in use one of Mr. Winslow's recording gages, and from the card which comes from the dial it appears that there is lost from the system during the twenty-four hours about 16 gallons per consumer. This is based on the loss from 12 o'clock midnight to 5 o'clock A.M. By taking this draft, when there should be little or no consumption, deducting the flow of three drinking fountains, and applying it to the entire twenty-four hours, an amount of 16 gallons, as mentioned above, is obtained.

Probably a very small part of this amount is legitimate use, but most of it is no doubt due to leakage from the pipe system, which is composed of 32.7 miles of cast-iron distribution pipe and 20 miles of wrought-iron cement-lined service pipe, a total of nearly 53 miles. In many houses there is more or less dripping from faucets due to defective washers or to the fact that they are not closed tightly. A little silt or a particle of solid material may lodge under a valve in a water-closet tank and allow the escape of a small amount of water. These leakages may often be too small to move the piston or disk of the meter, and thus be unrecorded.

As a matter of interest and information, I keep a record of the daily reading of the meter in my own house. During the last thirteen years the average daily consumption per person per year has varied from 12 to 24 gallons. This amount has been largely used within the house, but little being used for watering lawn or garden. The house for twelve of the years mentioned contained water-closet and bath-tub. Set tubs for washing were added last year and will, no doubt, act as a factor in increasing the amount of water used. There is no sewer system in Wellesley.

The facility with which water can be obtained and disposed of in a house has much to do with the amount used.

As previously mentioned, the average metered consumption in the town was 33 gallons per consumer. In my own family it has averaged for thirteen years 18 gallons per day per consumer. So far as indoor consumption has been concerned, only moderate care in the use of water has been exercised.

The use of meters in Wellesley has been entirely satisfactory and their use has saved the town many times their cost, in putting off the time when great expense will be required for a new or increased supply.

Our meters have been carefully attended to, and the cost last year for maintaining a little over 1 000 meters was $270, or less than 27 cents each.

There is probably no doubt, as Mr. Johnson has pointed out, that even with meters, owing to greater facilities in using and disposing of it, the consumption of water is increasing from year to year, but there is no question in my own mind that without meters the increase would be vastly greater. The results at Wellesley confirm this opinion.

Mr. George Cassell.* Mr. President, as Mr. Brackett has stated, Chelsea is one of the most wasteful cities in regard to water in the Metropolitan district, and in view of the fact that Mr. Johnson has made a statement to the effect that water meters do not accomplish the stoppage of waste (if this is true, I find myself in the position of advocating something that doesn't amount to anything), he has completely knocked my statements into a cocked hat.

* Superintendent of Water Works, Chelsea, Mass.

Now, I want to say a few words in relation to Chelsea and its consumption of water. Our city is supplied by gravity, is in the Metropolitan water district, and we are very cosmopolitan. We have a very condensed population, and a population of a character which should, perhaps, use more water than any other city; but we cannot all be Brookliners or Newtonians. [Laughter.]

Aside from the statement that the use of meters for stopping the waste does not accomplish the purpose, I believe that it is the only legitimate way in which to sell water to people who want to use it; especially in those cities that are in the Metropolitan district and where the water is purchased by measure. The old method of assessing by the fixtures, or otherwise, is antiquated and gone by. There is no justice in it; it is all guess work.

We started into the meter business because of the fact that we were attached, as I said before, to the Metropolitan water district, and the officials are not very slow in charging one for what he gets; and instead of coming down in price they keep going up. I don't know as I blame them any, because if the people are bound to waste the water they must pay the bill, and the only way to make them do so is by installing a meter and have them pay for what they use and waste.

In 1905 we had installed 951 meters. Previous to that our consumption was, I believe, 110 gallons per capita. In November of that same year we dropped to 82 gallons per capita, and of course I laid it to the use of meters, but I see that I was wrong. [Laughter.]

In December last we had a little cold snap and were informed by the state that the consumption had increased from two million and a half up to four million and a half per day, and that caused me to do a little thinking. I could only figure it out in one way, — that the increased consumption was due to the fact that the people were letting the water run to keep it from freezing. Now, I don't know in what sense Mr. Johnson used the word " legitimate " in connection with his view of it, but it didn't appeal to me, as the majority of those letting the water run were not occupying metered premises, and I have the practical side of it. Aside from that, however, in this steady cold snap that we have just had, the consumption increased until it got up to approximately

173 gallons per capita, or an increase from 3 000 000 gallons to 6 550 000 gallons daily, and that, according to Mr. Brackett's statement, was costing the people in my city approximately $150 a day.

Now the injustice of it comes right here. That was practically water which was wasted in consequence of the cold condition of the houses, the occupants of which let the water run to keep the pipes from freezing. As Mr. Thomas said, the houses were in such a condition that they had to let the water run to keep it from freezing. If that is legitimate use, and the people want to pay for it, all right, if the premises are metered and the state can supply the water.

Under the flat rate, the man who is not obliged to let the water run because his house is warm is the sufferer, as he is made to pay for what the other man wastes; but still they tell you it is an injustice to put a meter on his house to curtail that " legitimate," use of water by letting it run to keep it from freezing.

As I said before, we jumped from 82 gallons per capita in November to 173 gallons per capita during the cold period, which meant practically 91 gallons per capita waste; and if we could get along with 82 gallons per capita, including manufacturing and everything else, in November, why couldn't we do it every month? The question answers itself. It was simply because of the cold snap and the water being allowed to run until such times as tenants became satisfied that the weather was such that the water wouldn't freeze any more.

As previously stated, we have installed 951 meters. We collected with these during the year an excess of close to $10 000 over and above the minimum charge, which was $12 for the year. That was all very well in one sense, but it was hard on the water registrar in another, and as I happen to be the registrar in my city, I got the practical side of it everywhere. The fact remains, however, that if we are going to stop the waste of water we must educate the people up to the use of the meter, no matter what the result is, and I thoroughly believe that meters are the only legitimate means to stop the waste. You may talk about inspectors all you please. Why, there would have to be one stationed at every house!

One day I met a gentleman of Jewish extraction, a very nice man, and he said, " My God, Cassell, I paid $300 last quarter for water; what do you think of that?" " It is too bad," I replied; " how did it happen? " and he said, " The people in the houses let the water run to keep it from freezing." I said: " Those are nice houses that you have built down there and the plumbing looked all right; did you do anything to prevent the pipes from freezing? " He answered, "No." " Why didn't you pack the pipes? " I asked, and he replied, " What is the use? They will tear the boxing away and burn it up and everything that is around it." [Laughter.] I said to him, " Who is to blame? " " Oh," he answered, " the damned people who live in the houses. They are so damned ignorant you can't do anything with them. I put door strips on the doors to keep the cold out of the houses, and what do you think? They stole them all off." [Laughter.]

Now, that is exactly so. It is a hardship, we must all admit, upon the owners of houses who, no matter how patiently and conscientiously they try, cannot control the people who occupy them.

In our city we have a large but not very wealthy population, and a good many times I am surprised, when I get into an argument with gentlemen of my city, because they try to compare it with Brookline. [Laughter and applause.]

Now, gentlemen, mark me, I am not disparaging my city. There is no man more loyal to his city and the people in it than I am. I believe I am living in the queen city of the state. But it is not the city, it is the people. [Laughter.] Therefore I say that it is a hardship for us in this city, under its conditions, to try and establish a meter system. I heartily believe in what has been stated here before in relation to a watch or any piece of machinery,—I don't care what it is,—you cannot set it going and let it run without repairing or cleaning it once in a while, and expect to get good results from it. It is so with a meter; it ought to be taken out and cleaned and looked after, and then the result of that meter will be right.

It is not a superintendent's or a water registrar's business how the people use water, but it is his business to see that all get justice, and I don't believe there is any superintendent but is laboring to see that the citizens get justice, though in no

greater measure than the city receives it; that is, equal to all. And so I say that if we are going to reduce the consumption of water in our cities, we must stand the burden of everything that goes with it until we accomplish that result, and the only way we can accomplish it is by being firm and impressing upon the people that we are trying to do what is right by them, and educating them up to that fact, and until we have done that, and not until then, will we accomplish what we are all trying to do, namely, bring down the consumption of water in our cities to a point where it is reasonable.

When you look at it, in the city of Chelsea 82 gallons per capita in November and 173 gallons in these last two months (or since we had have this cold snap), 91 gallons waste per capita going through the sewers, costing $150 a day, for what? To allow men who own houses, — who won't exert themselves to put the plumbing in so as to protect the pipes from frost, — to allow them to accomplish their object at the expense of others who do not have to waste the water in this manner. The work of protecting pipes from freezing can be accomplished in one house just as well as it can be in another if it were not for the fact, as my friend before mentioned said, " You cannot educate them up to it."

Mr. Johnson. Mr. President, I should like to ask the gentleman who has spoken what the population of Chelsea is?

Mr. Cassell. Thirty-eight thousand.

Mr. Johnson. And $150 to keep pipes from freezing amounts to about how much per person?

Mr. Cassell. Well, I —

Mr. Johnson. Less than one third of a cent a day for each person to prevent the plumbing from freezing in the houses.

Mr. Cassell. Yes, but, Mr. Johnson, there are other things to be taken into consideration besides that, which, if I had the time I might state, but I don't think I will take up the time because there is a gentleman waiting to be heard on another matter.

The President. Keep right on, Mr. Cassell.

Mr. Cassell. Before the Metropolitan Water Works sprung into existence we obtained our water supply from the city of

Boston, and at that time there were periods in the summer and winter when, in order to get a supply of water to take care of the population (and it was a great deal smaller then than it is now), we had to install a pumping-engine and pump from the low-service into a high-service reservoir, and we had to do that in the hours of the night when the population was asleep, and if it had not been for the fact that the Metropolitan water works of the state of Massachusetts had been created, God knows what we would have done for water, — and we don't like it any better than the rest of you at that. [Laughter.]

Now, Mr. Brackett will corroborate what I say, that notwithstanding the fact that the state of Massachusetts has spent $40 000 000 to create a supply of water sufficient for all the cities and towns within a radius of ten miles of the State House, and, according to their best judgment, have put in aqueducts big enough to bring it down, I am informed that if this same waste took place everywhere it would be impossible for them to supply the amount without going further and spending more millions of dollars. So, Mr. Johnson, it is not the one third of a cent, but there are other things connected with it which must be taken into consideration.

Gentlemen, I thank you very kindly and I will close.

Mr. F. H. Hayes.* Mr. President, I have in mind the investigation which has been going on in a town for the last ten days in the matter of displacement of water with our pump. All the water going through the pump is going through a large meter. It is an electrically driven pump, with recording instruments from the General Electric Company, and the displacement of the pump indicates so much more water passing than does the meter that we are going to weir the water to see which is right, whether it is the pump or the meter.

The President. I should like to ask Mr. Hayes what his idea is of average pump slippage.

Mr. Hayes. Three to five per cent.

The President. That is, a new pump?

Mr. Hayes. Yes.

The President. How about an old one?

* Of the Platt Iron Works Company, Boston, Mass.

MR. HAYES. It depends on how gritty your water is.

THE PRESIDENT. How high slips have you known?

MR. HAYES. Oh, up to 50 per cent. You take a plunger pump traveling through a bushing without fiber packing and the slip is more than with the fiber packing. The pump we have in mind is a fiber-packed pump; it is a triplex pump; so we know pretty well that we are displacing the water; but we became so suspicious of the meter that was measuring the water, we have decided to submit it to weir measurement so we may know whether it is the pump or the meter, or where it is.

THE PRESIDENT. Or the weir?

MR. HAYES. Well, that will be up to the engineers.

MR. HENRY V. MACKSEY.* Judging from the arguments offered so far, it would seem that the general impression is that the author desires to prove that the use of meters will not prevent waste of water. I do not so understand the drift of his argument. Although he led us along with facts and figures to show that the first decrease in per capita consumption was not long maintained, he also said that in his opinion the use of meters was necessary and that their installation and use would surely continue. It would therefore appear that he does not differ materially from the many members of this Association who have studied this problem in all its phases for many years.

There is no doubt that many of the reasons offered to-day why meters do not continue to show the marked results secured on first installation are true. That the average meter is accurate and in good working order when first applied is undoubtedly a fact, but it cannot be expected to remain so forever. Water-works superintendents are usually compelled to produce great results on small incomes, and there is always a violent criticism of the cost of meter repairs by those who waste water and consequently despise meters. As the superintendent is usually very busy attending to his principal duty of supplying water at all times to all takers, and is hampered by lack of funds and of skilled labor, he often leaves the meters alone until they cease to register or break down, or prevent the flow of water on account of being stopped by rust or other foreign material. Then, out comes the

* Consulting Engineer, Boston, Mass.

meter. Suppose that the meter had been given as good care as an ordinary machine used in a shop gets; that it had been viewed once a year, or even once in three years, and was tested for accuracy and adjusted if necessary. Trouble and expense would have been avoided and a greater revenue would have accrued to the water department. It should be borne in mind that when a meter fails to do satisfactory work it is not useless. If the mainspring of a watch breaks or it stops on account of dirt, we do not throw it away. A dollar will pay for cleaning, or a new mainspring may be procured for from twenty-five cents to a dollar, depending on who does the work.

To say that the waste necessary to prevent freezing costs but one third of a cent per day per capita may be true, but that is not the proper way to look at the freezing problem. You should not figure on the bill for damage due to frost, in the general case, but on the interest on investment to permanently prevent freezing by proper construction. Mr. Thomas is certainly correct when he says that a dwelling wherein water freezes is usually unfit for human habitation. If we can force owners to so protect the plumbing in the dwellings of the poor that the water will not freeze, we will deserve credit for accomplishing a good work outside of our ordinary field.

That the per capita rate increases again after meters are applied should not discourage water departments. Remember that on a meter basis each taker is being charged for what he takes and no more, and that he can economize or be lavish in the use of water as he sees fit; and above all, let us not forget that the meter is not an instrument designed to discourage the use of water, but to stop waste or penalize the man who is responsible for that waste.

Mr. Brackett. Mr. President, I should like to ask Mr. Johnson how, if meters do not prevent the use of water to prevent the freezing of the service, does he account for the fact that cities and towns which are universally metered show very little increase in consumption during the winter season, while those which are not metered have, during cold weather, an increase of from 50 to 100 per cent.?

Mr. Johnson. Mr. President, perhaps my statement was a

little rash. What I meant by this statement was that a man who has a meter in his cellar would not be prevented from allowing the water to run if he thinks the freezing of his pipes would be prevented by that means. It may be that the introduction of meters will cause better plumbing to be put in; I have little doubt about it, not only in regard to freezing, but in other ways. I simply mean that on a particularly cold night, if I think that my water pipes are going to freeze, I will allow the water to run, meter or no meter, knowing that the increase in the water bill will be very small.

MR. J. C. GILBERT.* I have been very much interested in the address, and also in the discussion, but there is one thing which I think we have neglected to look into, and that is this: Supposing none of us had meters, or suppose, for instance, there were no meters; what would have been the increase in the use of water? Of course the people, if they do not have them, are careless with their water; and although you may catch a man once in a while and tell him that he must be more careful, he doesn't care much about that; but if you finally decide to put on meters, then they will see that you are after them and for a time they will be careful.

We have seen by the tables here that after putting on meters the consumption of water has decreased very quickly. One reason for that is because the people see what is coming, and they know that if they use water they have got to pay for it, and for that reason they are more careful.

All the houses that are built at the present day have more fixtures, more plumbing, and, of course, they require the use of more water. But if we hadn't put on meters, you would find that these water-works systems which are paying good dividends would have been in bankruptcy long before this time. I tell you that people would use water to-day at a fearful rate if no meters had been put on. I think we should have been obliged to do something radical to stop the waste. And now, after metering these systems, we find the more fixtures we have in a house the more water they will use, and that, of course, increases from day to day, until it gets up to nearly where it was before meters were put on, but we have nothing to show how much more the increase would have been had no meters been put on.

* Treasurer of Water Board, Whitman, Mass.

I believe in meters; I think that it is the only way to sell water unless you have all the water you want.

In my town last year we used 46 000 000 or 47 000 000 gallons of water, and we put in 85 new services, and we have metered nearly every one of them, and this year, when we came to figure up, we have only used about 42 000 000 gallons. Do you think if we had not metered those services there would have been a decrease in the consumption of water? I do not. I think there would have been a large increase. I believe that meters are a necessity, and I do not believe that the water systems to-day could be run with any kind of profit if it were not for meters. I think it is a blessing to the whole country that they are in use to-day.

MAYOR BLODGETT.* Mr. President, when you called upon me before I had nothing to say, but I have something to say now. I want to say, in the first place, that Mr. Johnson is the only man who has talked to my liking about water.

I want to answer just one question about going into bankruptcy if meters were not used. We have in Woburn not one metered service, but we have a water plant there that is absolutely free from debt. How many cities and towns are there here that can say that? Not one. Our water plant has yielded a revenue of $25 000 a year, and there is now a surplus.

MR. CASSELL. Mr. President, notwithstanding the statements I have made, and the statements that the gentleman made about bankruptcy, and the fact that we use a great deal of water, — notwithstanding all that, we had a surplus of $39 000.

MAYOR BLODGETT. What did you do with the $39 000?

MR. CASSELL. Well, they threw it into what they call the contingent account. It is something like a hole in the ground. [Laughter.] It is like one of those wells to which there is no bottom, and if you can go over there and find out where it went to, I wish you would.

Now, gentlemen, I want to say that I am very grateful to Mr. Johnson for his paper and his talk, and I think I voice the sentiment of every member of this Association. If it hasn't done anything else, it has brought up a discussion, which I think has been very enjoyable and has met with some favor.

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* Woburn, Mass.

MR. X. H. GOODNOUGH.* Mr. President, the charters originally granted to cities and towns authorizing them to supply themselves with water, did not contemplate the collection of a profit from the water works. It was assumed that only a sufficient amount would be collected from water rates to pay interest and sinking-fund requirements and the cost of management and operation of the works. The use of the water-works income for other purposes has, in fact, been specifically prohibited in some of the more recent water supply acts. If the latter practice shall become general, the cost of water to the consumer will eventually become very much smaller than it is to-day.

Under these conditions, in New England cities and towns, where the water works are, as a rule, well managed and the consumption of water is not unreasonably large, it can hardly be expected that in the long run any very material reduction in the use of water will follow the general introduction of meters.

Experience with water supplies in Massachusetts shows that there are comparatively few places in which records of the consumption of water are kept where the quantity consumed per person is unreasonably large; while, on the other hand, occasional measurements or calculations have shown that the quantity used in places where no continuous record of the consumption is kept is in very many cases excessive. In some such places the installation of a system for the continued measurement of the total quantity of water supplied to the city or town has been followed by a very material reduction in the use and waste of water without the general use of meters; and there can be no question that an actual knowledge of the quantity of water used leads to the prevention of illegal or unnecessary use and waste by the exercise of greater care and vigilance by the water-works authorities.

There can be no doubt that the general use of meters is a further check upon the excessive waste of water and tends to keep its use within reasonable limits, and the meter system is the simplest and most equitable method of distributing the water tax. It cannot be expected, however, that in places where the consumption of water is not excessive, the introduction of meters will reduce materially the consumption of water, or in places where the con-

* Chief Engineer, State Board of Health, Boston, Mass.

sumption is low, keep it from increasing, when the rates charged for water are diminishing.

Mr. Thomas. Mr. President, of course the reason why Woburn has no indebtedness and has a surplus every year is simply due to the fact that they charge more than they ought to. If every city and every water company in the state of Massachusetts charged more than they ought to, they would have a surplus and no indebtedness. It is all a matter of charging.

Mr. Fuller. Mr. President, it occurs to me that there is a great deal more water used to prevent freezing than there is needed for that purpose, and if just enough could be used to prevent that freezing, it would be a very small amount. I have occasionally let the water run to prevent freezing, though not very often, and I was surprised to find how little water it required. I think if the information could be spread abroad among people who allow the running of water to prevent freezing that it requires but very little, it would have a tendency to cut down this waste immensely.

The President. I am afraid, Mr. Fuller, that the only educator is the meter.

Mr. W. H. Richards (*by letter*). The tables presented by Mr. Johnson show, in a marked degree, the impossibility of comparing the consumption of one city with another without knowing all the factors which enter into the problem of per capita consumption. In a city where large quantities of water are used for mechanical or manufacturing purposes the operatives in the factories, who are a part of the population, are apportioned their share of domestic consumption and a portion of the water used for manufacturing purposes, thus raising the per capita consumption. On the other hand, in a city where a large proportion of the inhabitants consist of factory operatives living in houses without sanitary fixtures, where in fact, in many cases, the entire supply for several families is drawn from one faucet, the per capita consumption for domestic purposes is very low. This latter condition obtains in Fall River, and the per capita consumption there is further reduced by the non-use of water for manufacturing. Another factor in the problem is the sudden extension of the sewer system in a city, which often takes place several years after the introduction of water.

There is no doubt that in most of the cities mentioned in the tables there has been a sudden increase in the number of so-called sanitary fixtures in recent years, which tends to largely increase the per capita consumption, and a line in the diagrams showing this increase would probably account for much of the increase in per capita consumption after the introduction of meters. It is usual in most cities to meter all of a certain class of consumers at one time, and when the class where the greatest waste occurs is metered there is a sudden drop in the consumption, as shown on nearly all the diagrams, this showing the beneficial effects of meters in checking waste.

Does any man doubt that if all the meters were removed there would be a sudden increase in waste and a consequent increase in per capita consumption?

With the constantly increasing number of purposes for which water is used, it is probable that the quantity used per capita will increase for many years, but meters alone will keep down the waste and unnecessary uses.

There is one phase of the meter question which is often overlooked, viz., the equity of paying for water in proportion to the quantity used. There is no commodity, except water, which is sold at one price regardless of the quantity used. The injustice would be apparent if two bushels of potatoes were sold to one man for the same money as one bushel were sold to another man. Yet in the case of water at schedule rates the careful man pays not only his proportion of the expense of furnishing water, but also for the cost of furnishing his neighbor with water to waste; whereas under meter rates each pays for the benefit he receives and further pays for his neglect of consideration for his neighbor.

There are many questions in regard to meters which remain to be discussed as to the cost of accuracy, repairs, life, etc., but the fact of their efficacy in reducing waste is established beyond question.

MR. CLEMENS HERSCHEL * (*by letter*). The error lurking within the paper is one, it seems to me, of a misinterpretation and a wrong use made of statistics. I have always thought that hydraulics was a subject more capable of causing one to deceive

* Consulting Engineer, New York, N. Y.

himself than almost any other, unless it be the recognizing of the true meaning of, or the lessons to be drawn from, statistics; and when it becomes a question of properly using a combination of the two, the opportunities for self-deception become very great.

An inkling of one such error and of a class of such errors was given by President John C. Whitney when he referred to the construction of sewers while the statistics were being taken, and to the consequent change in the water-consuming habits of the people which developed during the statistic time. Mr. Sherman gave another argument against the acceptance of statistics taken in a formative community, — on the wing, as it were, — when he called attention to the fact that following the inauguration of a public water supply in a municipality comes a period in which the citizens learn to use water and put in fixtures to draw water. Naturally no correct use can be made of statistics taken during the course of such an era of water-works extensions without the houses of the people and within them. From data of this sort all those not strictly analogous and sound in every way must first be carefully culled out before they can properly be used in the diagrams made for the determination of facts or laws.

To illustrate: Take Table No. 1, on page 113. What does the paper care for the different characteristics or modes of government of the different cities cited? Some I happen to know something of. There is Bayonne, N. J., the home of the very large works of the Standard Oil Company; which alone, besides the Orford Copper Company and other minor manufacturing concerns, consume millions of gallons of water daily. I doubt if the consumption of water in Bayonne by consumers such as are found in the *average* city of that size is to-day so much as 40 gallons per person, and some years ago it was about 30. Under these circumstances what right has any one to call 100 one coördinate of a pair of rectangular coördinates, and write 95 in the other column for Bayonne, as is done in the table? How many more such defective figures are there in the table? And in the diagrams based on it, and in similar tables?

We are told that Brockton, Fall River, and Providence may likely be found, before long, less of an example to the others than they have been. Will that be on account of a proper increase in

the use, not waste, of water? Or will it be because by change of administration, or similar causes, vigilance and skill in the finding and remedying of leakage and waste of all sorts has relaxed, perhaps joined the majority?

We hope not. For we have largely profited by, and need, more than ever, their bright example.

Is it not all wrong to lay weight on and use, as the basis of diagrams from which to deduce laws, a set of statistics that deal with the effect of metering 25 per cent. of the taps of any one city? What does that teach us of the *character* of the draft from either the 25 per cent. or from the remaining 75 per cent. of the taps?

When left to the consumers it is the wise and thrifty who put in meters, while the shiftless and wasteful fight against them, and prefer to let the others pay for the water they themselves waste.

It will not do to infer merely from statistics taken with a free, liberal hand, and then plotted on an assumed system of rectangular or other coördinates. Instead of this, a lot of thinking about the true and precise meaning of each item, and of culling out, must be kept up to permit of valid deductions being drawn from the finally remaining lot.

It is said that Lord Palmerston, prime minister of England, once called in his chief statistician, wishing to be informed as to pending legislation on, we will say, the culture of rice, and asked him to go and prepare for use the established statistics concerning rice. Much to Lord Palmerston's surprise the man hesitated and hung back, and being asked why he did not go and do as he had been told, blurted out, " But, my lord, what is it you wish to prove? " He had facts enough on file, but according as his statistics were handled and marshaled, they could be made to support one feature of an argument or another.

Can we not do better than limp along in this matter with leaden feet, in the distant wake of uncertain and obsolescent statistics?

Nobody wants to reduce or restrict legitimate use, or cares particularly just where laudable habits of the people will bring it. What we are after — our ideal aim — is the utter annihilation of *waste;* and the complete way to accomplish this is to start fair, or to bring waste to a reasonable figure, and then to maintain that condition; and the way to do this is to make a daily, if

possible, — at all events a short term, — continuous routine comparison between income and outgo. In a paper I expect soon to publish I have said as follows:

The case of the East Jersey's Water Company's fifty miles of pipe line has already been given as an example of water waste prevention by a controlling and checking of leakage as it arises. On that method of work hang all the law and the prophets relating to water-waste prevention in any kind of a hydraulic plant. In the last analysis the prevention of water waste depends on naught but a daily measurement of income and outgo, and the keeping of these two in constant agreement. If a meter be placed at each end of a pipe line 23 miles long, as was done when the conduits of the East Jersey Water Company were built, it is very evident that the daily records of these two meters must agree, or else there is something wrong about either the meters or the pipe line; and if the meters are in order, leaks must be sought for and remedied on the pipe line between them.

In a larger sense the above-described procedure is all that is necessary to control and check waste and leakage on any kind of a pipe-line or system of pipe-lines up to the complex, but to treatment perfectly amenable, case of water supplied to a city district and consumed within it by resident families, shops, and manufactories.

This opens up a large subject, but ill undersood, especially so in the United States, where a street-main leakage of 20 gallons per inhabitant and more is considered an infliction of Providence or due to the climate, or to the peculiar habits of free-born Americans, or to most anything else than to the municipal shiftlessness not infrequently encountered in the United States, or to lack of the proper amount of work expended to control street-main leakage by the water-works administration; which alone has allowed it to grow to the existing serious dimensions through the course of perhaps fifty years of frequent changes of administration.

Nor will spasmodic examinations and reports made upon them change the situation. This is only the old story of house-to-house inspection of plumbing fixtures to prevent waste on the consumers' premises over again, and as applied to the case of cities wasting out of the street-mains. So soon as the inspector's back is turned, waste renews its insidious work and is once more on the increase.

There is only one way to keep control of street main leakage, and that is by a continued system of frequent, or so long as it is necessary, of *daily* measurements; best by means of twenty-four hour chart records, which will serve to note the course of or *the*

beginnings of sources of waste, and by thus first placing and then keeping waste under subjection.

The city should be divided into districts, any one of which could be shut off from the rest and have its supply graphically and continuously measured and recorded at any time, day or night, and as long as desired. Then by well-known means, all consumers should be metered; and once the accuracy of these meters is known, leaks and waste outside of the consumers, premises can likewise be sought for and remedied.

In an examination of this sort once made by Mr. Winslow H. Herschel, civil engineer, a son of the author, the final result was that it would be profitable for the city to meter every tap and also to check waste out of street mains, as thereby that city could be made to supply its then inhabitants, and its future growth of inhabitants as well; for *fifty years*, from the quantity then consumed (used and wasted) within its city limits.

As the situation in the United States in the respects referred to may not be known to the reader, it is proper here to say that one city frequently commits the folly of pumping over 400 gallons per inhabitant per day into the sieve that represents its distribution system, the wide-open plumbing fixtures of its inhabitants included; and 350 gallons per inhabitant is an ordinary quantity to be consumed in that city.

A school of water-works philosophers and bodies of complacent officials have grown up who will argue that 150 gallons per inhabitant is too small a quantity to provide for a city, when half that quantity could readily be reached or approximated; and that city water main waste cannot be reduced to the terms that obtain in Europe; or in the distribution of gas in cities at home (frequently as low as 12 per cent. of the output). Yet all this time the city of Providence, R. I., in the United States, a city of some 200 000 inhabitants, the center of a large suburban district, housing many thousands of transient visitors daily in addition, and a large manufacturing center as well, has never consumed much over 60 gallons per inhabitant per day, and has brought this about by mere ordinary methods of good housekeeping; while smaller places in the United States have approached or reached 30 gallons per inhabitant.

There is room for much good work to be done, so much is evident, and though hitherto the laborers have been few, signs are not wanting and are indeed active that a permanent work of municipal water waste prevention will take up much of the attention of American engineers in the future.

MR. PAUL HANSEN * (*by letter*). This is an exceedingly val-

* Assistant Engineer, State Board of Health, Columbus, Ohio.

uable paper and is the first in which such extensive data have been brought together to show the effect on consumption of metering a public water supply. It is instructive in showing both the advantages and limitations attending the use of meters. With the advantages we are more or less familiar, but the limitations are brought out only by a careful study of facts and are not very apparent from theoretical considerations. Further, the paper brings out, in a striking manner, the value of a pure water supply in reducing waste consumption, an economic advantage that needs to be brought forcibly to the attention of many water-works officials.

Following out the logical lesson of Mr. Johnson's studies, it should be recognized that the apparent failure of meters to reduce water waste is not due to the inability of meters to accomplish this result, but to the fact that nearly all of the supplies considered are imperfectly metered. If on a given water supply *all* services were metered and a good meter also placed on the discharge main from the pumps (or conduit main in case of a gravity supply), the detection of any serious waste would be a comparatively simple matter. This applies equally well to waste of energy through slip of the pumps. The few measurements of slip on water supply pumps in the state of Ohio would indicate 25 per cent. to be the rule, and in one case, and that a pumping engine of no mean size, the slip was 40 per cent.

Furthermore, the universal use of meters involves the keeping of more complete records, which in itself is a great gain, for great sums of money are lost by inefficient operation, which inefficiencies are never discovered for lack of figures to bring them out. While no exact figures are available, an examination by the writer of a large number of water supplies in the state of Ohio has convinced him that many thousand dollars could be saved if only the difference between the actual amount of water pumped and the calculated amount as registered by the pump revolution counters could be ascertained. At least as much more could be saved if the difference between the actual amount pumped and the amount paid for by consumers could be ascertained. If by the universal metering of a supply the waste could be kept down to a reasonable amount, the increase in consumption in all but

a very few exceptional cases would be entirely unobjectionable, for the water used would be paid for and any increase in consumption would then fully justify a corresponding extension of the supply to meet such consumption. Thus, to the writer's mind, the point most forcibly shown in Mr. Johnson's excellent paper is the necessity for the complete metering of supplies in order that the best results may be obtained.

MR. E. M. PECK * (*by letter*). I feel it not only a duty but a privilege to commend Mr. Johnson's paper; and while most of the statements he advances have become fairly well known to active water-works men, I doubt if ever before they have been so comprehensively and convincingly presented as in this paper.

The statement that because meters have accomplished a certain result in one city they need not be expected to accomplish the same results in any other city is eminently true. Every tub must stand on its own bottom, and while results in one city may be taken as an indication of what may be looked for by a similar treatment in other places, a study of conditions prevalent in each city must be made and its salvation worked out independently. In working out the effect of meters upon the consumption of water in any city, and especially in doing this comparatively among different cities, we are at once confronted by the paucity of statistical records. Many very indefinite quantities enter into the problem. For instance, in a city of any considerable size, the non-resident and floating population is an element to be considered. It will be remembered that when Mr. Nicholas S. Hill, as chief engineer of the water department of New York, was making elaborate water-waste surveys in that city, he found in certain sections what appeared to be enormous waste. When an analysis of the population and business enterprises of these sections was made, however, it was found that including the non-resident population the consumption was, in reality, remarkably low.

If my recollection is not at fault, the statement made at that time was that the floating population of Greater New York was estimated at between 500 000 and 600 000. In my own city, after a good deal of investigation, I am accustomed to call the non-resident population equivalent to 3 000 regular water consumers.

* Distribution Engineer, Hartford Water Works, Hartford, Conn.

Another common source of error in pumped supplies, where the rated capacity of the pumps is the only means of measurement, is in making wrong allowances for slip.

Where a large percentage of the taps are metered there is danger of arriving at wrong conclusions on account of the under-registration of meters. In my own city not long since, out of 201 meters tested, 31 registered less than 98 per cent. of actual flow, the range of percentages of registration being from 84 to 97.82.

Of the 201 meters above mentioned, 19 registered over 102 per cent. of actual flow, but inasmuch as the worst case exceeded this figure by only 1.73 per cent., it will be seen that the over-registration need hardly be considered.

In figuring upon leakage and waste, sight is lost frequently of private fire-service pipes. In my own opinion, if these were either all metered or subjected to rigid control of some kind, many a water-works department would be able to make a much closer accounting for its water than it now can.

There is no doubt whatever, as Mr. Johnson says, that the first effect of meters when set in considerable numbers is to reduce the consumption. For a short time they seem to frighten the consumer into exercising the greatest care, not only in the necessary use of water, but in keeping plumbing in repair as well. After he receives a few bills under the meter system he is apt to discover that if anything he is paying less than under assessment, and his care at once relaxes, with the result that consumption increases.

That what might be called the necessary consumption of water is increasing, I think there is no doubt. I also doubt if any meter system will reach its highest efficiency in reducing consumption unless coupled with a rigid leak inspection both inside and outside the premises.

Metering of the city of Hartford was begun in 1900 and completed in 1903. According to the best information at my command the per capita consumption before general metering was commenced was about 84.6 gallons. Since that time the average per capita consumption by years has been as follows: 1901, 75.5; 1902, 77.2; 1903, 74.2; 1904, 66.4; 1905, 62.8; 1906, 64.7.

It will be noticed that the most remarkable decrease in consumption occurred in the year following the completion of metering, 1904.

During this year and since that time, however, a very thorough investigation for leaks all over the distribution system has been maintained, which I think accounts for the sudden drop. The consumption of the year 1906 would indicate that in spite of meters and leak inspection, increased use of water is making itself felt.

In this connection, however, I will say that my opinion is that the population of the city has increased much more than we suppose, and that if the true figures were known the apparent per capita would be somewhat reduced.

Mr. Morris Knowles * (*by letter*). The Association is fortunate in having presented so clearly much valuable information regarding this problem which, while it has long been before us, is yet little understood by the mass of the people. The author deserves our thanks for his labor and painstaking care in bringing out important data, some of a novel kind, and the deductions from them.

The writer does not agree with all the conclusions, but neither does he believe, with some, that this article, written with these ideas, will do harm and create a sentiment against metering. There is some popular cry against the use of meters, due to many different causes, but this is not general among those who intelligently look into all phases of the subject, unless political or personal financial reasons cause a bias. The truth cannot hurt, and facts honestly presented and intelligently discussed can operate only for good. If the facts now brought out should indicate that metering is not so valuable as has previously been supposed, no amount of blind following of old dogmas will long keep the proper light hidden; thoughtful consideration is best.

The writer, however, does not believe that the facts show a failure in meters to do that which may properly be expected, namely, to reduce the waste and improper use of water and to prevent an extravagant increase. For a long time many have anticipated too much from metering alone, and it is but reasonable that thoughtful consideration of facts will show that other investigations and rigid inspections should go hand in hand with the general introductions of meters. Furthermore, while the general

* Chief Engineer Bureau of Filtration, Pittsburgh, Pa.

use of water is increasing, due to the several causes mentioned by the author, and most of all due primarily to the prosperity of the country and the general lavish conduct of the American people, waste and excessive increase are checked by the use of meters, especially if other precautionary measures be adopted.

Several years ago, in considering the use of water for the city of Pittsburgh, the writer, in coöperation with Mr. A. B. Shepherd, superintendent of the Bureau of Water, made an estimate of the probable saving that could be made with the introduction of meters and careful restrictive measures and investigations. Considerable criticism developed, due to the fact that the capacity of the filtration works was based upon an ultimate figure of 125 gallons per inhabitant per day, and that the works should be prepared to deliver at first the amount of water then being used. Many persons, believing that two thirds of the water was wasted, thought that the use of 253 gallons per person per day at that time should be brought down to about 85. This is but an example of two great expectations, — a forgetfulness that certain places may naturally use more water than others, and also that works should be designed for that which is rather than for that which should be.

At the time of making these estimates for the city of Pittsburgh, data were secured from most of the cities in this country having more than 25 000 population, and this information was plotted to show the relation between the per cent. of services metered and the daily use of water per inhabitant. This diagram has recently been brought down to date and it is reproduced in Plate II. The most important thing to engage attention is that the recent knowledge does not materially change the general appearance of the diagram. For the purpose of comparison, the average line made up from Mr. Johnson's data for five groups is plotted as RST.

The completed line for the city of Pittsburgh for the last few years is particularly instructive, and it is remarkable and seems almost beyond belief that for the year 1906 the line strikes almost exactly upon the point predicted under normal conditions of introducing meters.

A few words may not be amiss about the slope of this line. It

is probable that the 1903 stated use of water was too high; the over-estimate was due to the fact that for a long time the pumps had been working without much rest for overhauling and repairs, and the turbid and gritty water had developed a large amount of wear in the valves, and thus a large amount of slip and an over-estimate of the pumpage. With the addition of two new pumping engines, made available in 1904, and the slip thus reduced, it will be seen that there was a sudden drop in the use of water per person. The new figure was probably the more correct one for the previous year or two. Meters have been introduced, and out of a total number of about 6 500, very nearly one third are in one district, using one twentieth of the water. The marked drop during the last year has also, in part, been due to a thorough pitometer investigation and house-to-house inspection, mostly in this same district.

It may be of interest to give the statistics of this district, which is a good example of what can be accomplished, not only with thorough metering, but even after, by a careful study of the losses in the mains and by a house-to-house inspection. This district, which comprises a certain high territory supplied from the Bedford reservoir, is one which is easily separated for this purpose; and by the courtesy of Mr. A. B. Shepherd, superintendent, the writer is enabled to present this valuable information. It should be remembered, however, that while meters have been largely introduced, payment is still made at the fixture rate, there being no ordinance compelling the purchase of the water by meter. The following are the statistics of this district:

Size of the Bedford District	286 acres.
Population, estimated to be the same as at the census of 1900	27 241 persons.
Population supplied through meters	16 800 persons.
Number of houses	3 773
Number of services	2 580
Average population per house	7.2 persons.
Average population per service	10.5 persons.
Water mains in the district	13.5 miles.
Population per mile of main	2 016 persons.
Services per mile of main	191
Character of district, tenements; plumbing, old and generally poor.	
Daily quantity of water entering the district at beginning of the investigation, August 1, 1906	4 325 000 gallons.

Daily quantity of water entering the districts at close of the investigation, April 19, 1907	3 025 000 gallons.
Saving per day	1 300 000 gallons.
Per cent. of water saved	30
Per cent. of services metered	74.8
Per cent. of water measured by meter	43.7
Water used per person per day before investigation	158 gallons.
Water used per person per day after investigation	111 gallons.

From the known night waste it is estimated that one third of the 111 gallons is still a constant loss.

In Fig. 14 there is shown, in a graphical way, the results in this same Bedford district, showing the decrease in the use of water per inhabitant, month by month, and the corresponding increase in the per cent. of services metered. The latter months of the diagram show the further decrease, as detailed in the above tabulation, with the per cent. of services metered remaining the same.

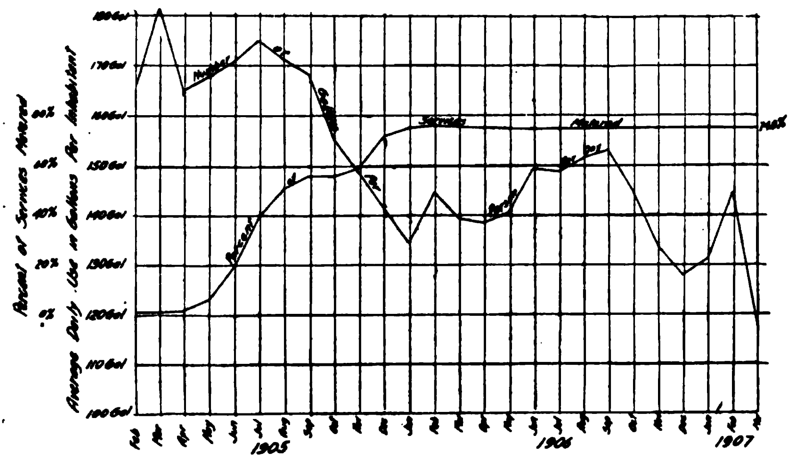


FIG. 14. EFFECT OF METERING AND INVESTIGATION WORK IN BEDFORD DISTRICT, PITTSBURGH, PA.

As a further study into the problem of what metering means to cities, we have plotted, in Figs. 15 and 16, results from various cities in the country. These are divided into two groups; Fig. 15 contains those in which less than 15 per cent. of the services

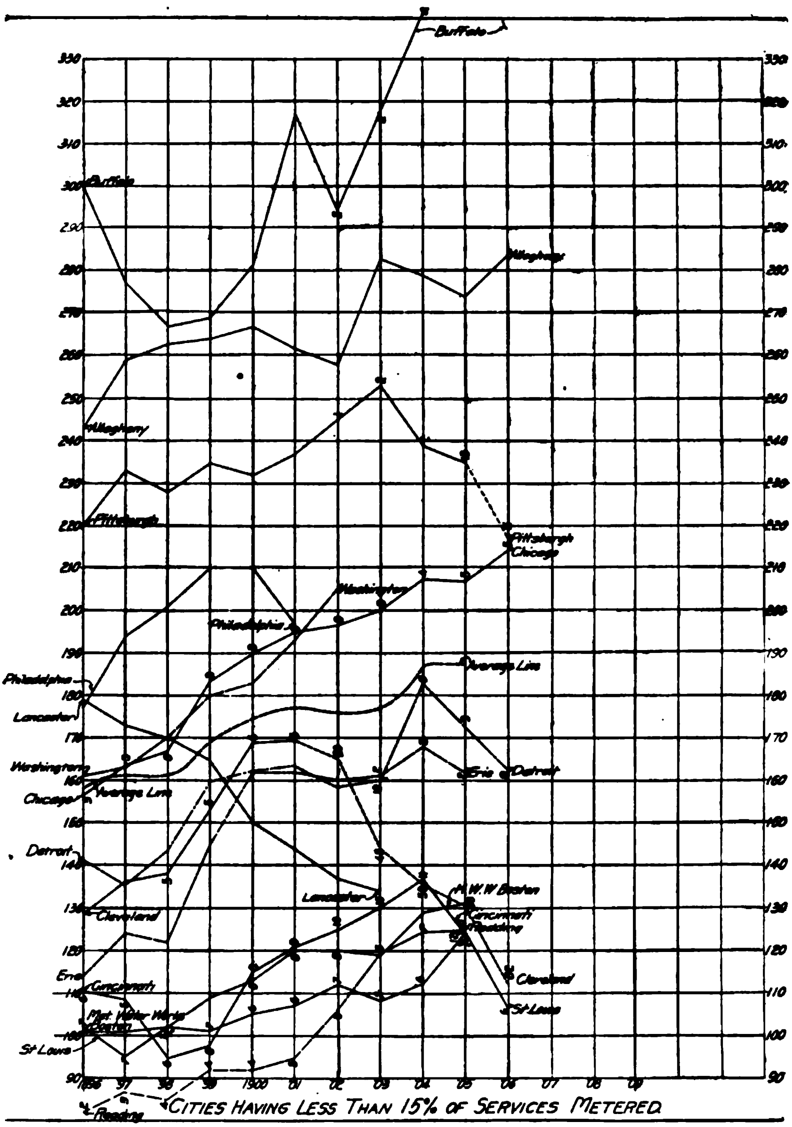


FIG. 15. FLUCTUATIONS IN THE PER CAPITA USE OF WATER IN CITIES WITH SMALL PERCENTAGES OF SERVICES METERED.

are metered; and Fig. 16 those in which more than 50 per cent. of the services are metered.

The most striking result is the very large consumption in the first group and also the erratic behavior of the lines, showing probably that spasmodic efforts have operated to reduce the

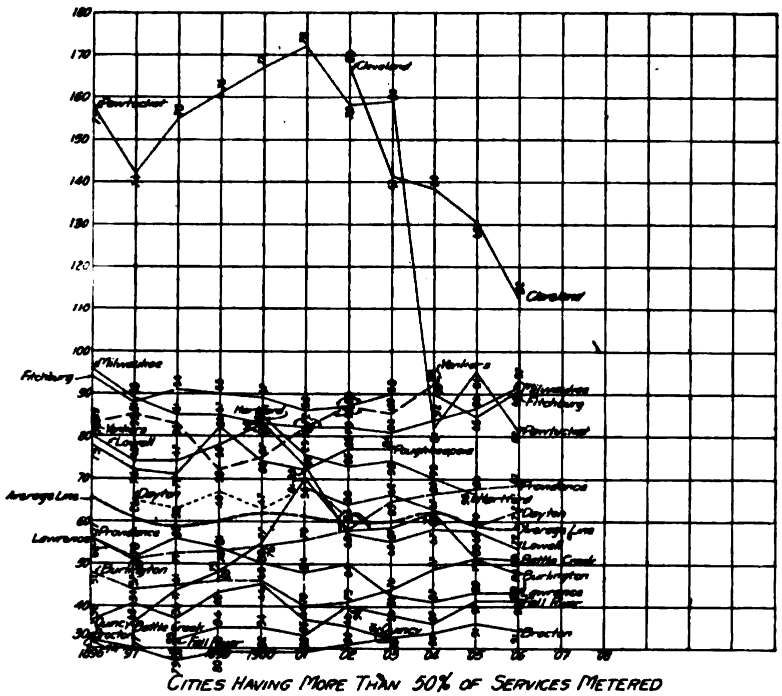


Fig. 16. Fluctuations in the Per Capita Use of Water in Cities with Large Percentages of Services Metered.

waste. In the second group it is to be noticed that the use of water is low, with two exceptions, and the lines follow about the same course, showing but little increase, if any.

The average line in the first group increases 29 gallons in ten years, while the average line of the second group decreases 8 gallons in the eleven years. The latter does not include the effect of the two erratic cities at the top of the diagram. This would

seem to give other evidence than that shown upon Mr. Johnson's Fig. 1. The writer, however, does not pretend to say that metering alone will always cause a reduction, or that, without increasing the use of meters, the line of the use of water will not have a general tendency upward. Eternal vigilance is the price to pay for curtailing waste and keeping an increase in the use of water, as well as other commodities, within reasonable limits.

There is one important factor shown by all of these recent investigations, and that is, that meters do not curtail a reasonable use of water for ordinary household purposes. It is important to dwell upon this because the advocate of meters frequently meets with opposition from this standpoint.

Mr. Johnson has advanced the novel claim that where water is of good quality, there will be less used. This is worth considering, and the writer has already called attention to the fact that, where water is muddy and gritty, there may be another reason for apparent excess, due to excessive slip, which is not always properly estimated and frequently not high enough.

The writer cannot agree that the winter waste is negligible, nor is it true that all cities will show the same months for increase as that shown for Massachusetts in Mr. Johnson's Table No. 6, page 129. A similar statement for Pittsburgh is given in Table No. 13. Another truth is not shown, namely, that the days of largest pumpage are frequently in the winter time.

One of the last items mentioned, namely, that the per cent. of water accounted for is small, has always been a startling revelation to those who have investigated this matter. It shows that there are likely to be places of large waste besides the house plumbing, and this is a strong argument for other means of investigation and for large meters upon the principal water mains supplying given districts, so that the total quantities coming into a district can be determined.

The writer is glad to heartily concur in the closing paragraphs of the author, and to express the belief that by the dissemination of such data we will come to a more thorough understanding of this interesting problem.

TABLE No. 13.

PER CENT. WHICH MONTHLY USE OF WATER IS OF THE AVERAGE, TOGETHER WITH AVERAGE RAINFALL AND TEMPERATURE FOR PITTSBURGH.
(AVERAGE OF ELEVEN YEARS, 1896–1906.)

	Per Cent. of Average Use of Water.	Rainfall. Inches.	Temperature, Degrees Fahr.
January	98.8	2.14	31.1
February	103.8	2.29	29.0
March	101.3	3.90	41.4
April	99.1	2.96	51.2
May	97.7	3.03	63.9
June	99.5	4.61	70.5
July	102.0	3.99	75.3
August	102.3	2.94	73.4
September	102.0	2.14	67.6
October	98.7	2.29	56.5
November	96.4	2.22	44.1
December	99.7	2.63	33.3

MR. JOHNSON (*by letter*). Judging from some of the foregoing discussions, certain of the conclusions in my paper cannot have been clearly stated. I have not attempted to show, nor have I suggested, that meters do not reduce the waste of water in houses. What I have shown is rather that high consumption does not necessarily mean wastefulness on the part of the consumer, and that it cannot, in all cases at least, be reduced to a low figure by the introduction of house meters. I am very far from condemning meters as being worthless, but rather would condemn the extravagant claims made as to what they will accomplish.

It is unfortunate that in order to secure the introduction of meters, water-works officials so often find it necessary to make claims as to the great economy in their use which cannot be substantiated. As a matter of fact, there are much better reasons why meters should be used than the mere reduction in the consumption of water, and even if it is found to be cheaper, as in some cases it will be, to supply the excessive quantity of water wasted than to install and maintain meters, yet the use of meters is justified in order that the cost of the water may be equitably assessed. Mr. Richards has expressed this very well in his discussion.

In an effort to accomplish a reform we are too apt to see only those facts which are favorable, shutting our eyes to those less favorable. The cases of Fall River and Brockton are always cited, but we seldom have brought to our attention the many cases where meters are in general use but the consumption remains high. In this paper all of the places concerning which information could be obtained have been included and the facts are presented for what they are worth.

Mr. Brackett in his discussion has unconsciously emphasized the point which I have tried to make in regard to dangers in the selection of certain facts while ignoring others which are equally applicable. He speaks of the high winter consumption in the cities of Boston and Chelsea, which are practically unmetered, and compares the consumption in these places with the low winter consumption in the metered towns of Belmont, Malden, Milton, and Watertown. That the low winter consumption in the latter places is not due to meters alone can be shown by a comparison with the consumption in other cities in the Metropolitan District where meters are not used and yet there is no excessive consumption in winter. The following table is introduced to supplement Mr. Brackett's table by giving *all* the facts. The figures are taken from Mr. Brackett's discussion.

	Per Cent. Services Metered, 1906.	Average Nov. and April, 1906 (Gallons).	Average Four Winter Mos. in 1906 (Gallons).
Boston	5	143	160
Somerville	19	82	88
Malden	78	49	50
Chelsea	10	87	109
Everett	2	73	86
Quincy	3	99	104
Medford	8	93	94
Melrose	3	106	109
Revere	4	67	75
Watertown	93	66	60
Arlington	22	74	73
Milton	100	42	38
Winthrop	2	97	102
Stoneham	2	67	64
Belmont	100	53	44
Lexington	2	71	61
Nahant	18	71	69
Swampscott	0	73	74

Mr. Brackett's statement that in places having a population of less than 50 000 the average per capita consumption should not exceed 50 gallons I will not dispute, but the fact remains that it *does* exceed this amount, and even in the Metropolitan District, as shown by Mr. Brackett's table, there is only one town having a consumption less than 50 gallons per person per day. Furthermore, as stated in the paper, the use of water is increasing at a rapid rate notwithstanding the use of meters, and we must face the fact that if the consumption is to be reduced to 50 gallons per person, it will not be by the use of domestic meters alone. As Mr. Knowles has said, "Works should be designed for that which *is* rather than that which *should be.*"

Mr. James H. Fuertes, in his recent report to the Merchants' Association of New York, has made an excellent analysis of the use and waste of water in New York City, and his conclusion is that while a much larger quantity of water is wasted in various ways, the maximum reduction which can be expected by the general use of meters is 15 gallons per person per day. This I am convinced is a reasonable figure to apply to the average unmetered city where the consumption is from 75 to 100 gallons and where there are no unusual conditions.

The point raised by Mr. Sherman as to the increase in the per capita use of water with the age of the works is a good one, and the following table, giving the average consumption in a large number of places, is presented to show the rapid increase in the use of water in the years immediately after the construction of works, due probably in a large measure to the increase in the number of consumers:

TABLE SHOWING INCREASE IN CONSUMPTION OF WATER, WITH AGE OF WORKS.

Year after Water was Introduced.	Consumption. Gallons per Person per Day.
1	22
2	27
3	34
4	36
5	40
6	40
7	38
8	41
9	41
10	42

Mr. Whitney has suggested the effect of the introduction of sewers upon the consumption of water, and the following table is presented which gives the best data which I have been able to obtain in regard to this. The difficulty in collecting such data is that in most cases the sewerage system is of gradual growth, and there are few places where it can be said that in a certain year a complete sewerage system was introduced.

TABLE No. 14.

CONSUMPTION OF WATER IN FIVE CITIES AND TOWNS BEFORE AND AFTER THE INTRODUCTION OF A FAIRLY COMPLETE SYSTEM OF SEWERS. (GALLONS PER PERSON PER DAY.)

City or Town.	Year Previous to Introduction of Sewers.							Year when Sewer System was Practically Completed.	Year Subsequent to Introduction of Sewers.						
	7	6	5	4	3	2	1		1	2	3	4	5	6	7
Marlborough	13	17	20	21	24	24	25	26	30	30	35	34	37	37	38
Newton	28	31	33	33	31	36	40	42	50	52	60	65	63	60	57
Waltham	37	36	39	33	31	32	33	40	47	53	61	59	71	70	76
Natick	27	29	34	37	40	41	43	46	41	40	42	40	38	42	51
Woburn	60	51	58	54	56	65	69	73	72	68	70	78	78	82	85
Average	33	33	37	36	36	40	42	45	48	49	54	55	57	58	61

A NOTE ON THE SPONTANEOUS IGNITION OF GAS FROM SEWAGE.

BY PROF. W. P. MASON, DEPARTMENT OF CHEMISTRY, RENSSELAER POLYTECHNIC INSTITUTE, TROY, N. Y.

[*Contributed April 17, 1907.*]

At the time of presenting my suggestion that phosphine was probably the agent that ignited the gas mixture in the Saratoga septic tank, which resulted in an explosion that wrecked the structure,* I was not possessed of any data in support of the proposition excepting my observation of gas bubbles which burst into flame as they escaped from the water off the New York docks. I am now in receipt of a letter from Mr. J. H. Fewell, superintendent of the Water Company at Jackson, Miss., in which he says:

"Through the kindness of some fellow member of the American Water Works Association I received a copy of the proceedings of the New England Water Works Association and carefully read your article in reference to the cause of the explosion which wrecked the septic tank at Saratoga, N. Y. It seemed from the discussion which followed that some of your fellow members were a little in doubt as to the correctness of your theory. Some time ago I was out on Pearl River near this city and near our pumping station. There I witnessed a very curious phenomenon. I observed some distance from the shore a great many very large bubbles which came rushing up from below, and when each one reached the surface it burst and a greenish flame would shoot up several inches. I watched it for quite a period of time and was much interested to know about the cause and to have it explained to me, so your theory is timely."

This would seem like some confirmation of my contention. Doubtless the phenomenon occurs but seldom, because of adverse conditions, and one might readily grow weary of watching for it at a sewer outfall, but such an occurrence is apparently not unknown, and it is the part of wisdom to bear in mind the possibility of its happening.

* JOURNAL N. E. WATER WORKS ASSOCIATION, March, 1907, p. 23.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, March 13, 1907.

The March meeting of the Association was held at the Hotel Brunswick, Boston, at 2 P.M., on Wednesday, March 13, 1907.

President John C. Whitney presided, and the following members and guests were in attendance:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, J. W. Blackmer, C. A. Bogardus, George Bowers, Dexter Brackett, G. A. P. Bucknam, George Cassell, C. E. Chandler, J. C. Chase, C. E. Childs, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, A. W. Cuddeback, L. E. Daboll, John Doyle, H. P. Eddy, I. T. Farnham, F. F. Forbes, A. N. French, F. L. Fuller, E. F. Garvey, J. C. Gilbert, A. S. Glover, X. H. Goodnough, F. W. Gow, E. H. Gowing, R. A. Hale, J. O. Hall, G. W. Hawkes, T. G. Hazard, Jr., J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, Morris Knowles, C. F. Knowlton, E. E. Lochridge, A. R. McCallum, H. V. Macksey, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Mayo, F. E. Merrill, William Naylor, O. E. Parks, C. A. Perkins, H. E. Perry, W. H. Richards, L. C. Robinson, Ransome Rowe, H. E. Royce, A. T. Safford, H. W. Sanderson, A. L. Sawyer, E. M. Shedd, C. W. Sherman, G. H. Snell, G. A. Stacy, W. F. Sullivan, L. A. Taylor, R. J. Thomas, W. H. Thomas, J. L. Tighe, J. A. Tilden, D. N. Tower, C. A. Townsend, W. H. Vaughn, C. K. Walker, R. S. Weston, J. C. Whitney, F. I. Winslow, G. E. Winslow. — 79.

Associates.

Harold L. Bond Company, by Harold L. Bond; Builders Iron Foundry, by F. N. Connet; Coffin Valve Company, by H. L. Weston; The Fairbanks Company, by F. A. Leavitt; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey, and H. V. Macksey; International Meter Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; The Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by Fred N. Whitcomb; Thomson Meter Company, by Edward M. Shedd; Union Water Meter Company, by F. E. Hall and F. L. Northrop;

United States Cast Iron Pipe and Foundry Company, by Frank W. Nevins; R. D. Wood & Co., by William F. Woodburn. — 24.

GUESTS.

James G. Hill, water commissioner, Lowell, Mass.; E. T. Harvell, water commissioner, Rockland, Mass.; C. D. Baker, superintendent, Abington, Mass.; C. W. Gilbert, and William E. Blodgett, Mayor, Woburn, Mass.; Sumner W. Hildreth, engineer, Westfield, Mass.; J. B. F. Breed, Esq., chief engineer, Commissioners of Sewerage, Louisville, Ky.; William A. Breed, superintendent, Norwich, Conn.; Major E. S. Horton, Carl G. Kritson, Attleboro, Mass.; Mr. George W. Stiles, superintendent, and Charles T. Hall, water commissioner, Malden, Mass.; F. L. Clapp, superintendent, Stoughton, Mass.; E. H. Palmer, Reading, Mass.; A. E. Blackmer, Plymouth, Mass.; J. B. Newhall, Stapleton, S. I. — 16.

[Names counted twice — 7.]

THE PRESIDENT. We have a guest with us who has consented to address us briefly. I have the pleasure of introducing Mayor Blodgett of Woburn.

MAYOR WM. E. BLODGETT. I have had occasion in my life sometimes to feel the influence at the polls and elsewhere of the liquor dealers' association, but this is the first time that I have ever come under the influence of the water dealers' association; but so far as my experience goes I would prefer the water cure to the other.

I suppose I am called upon here as a sort of a horrible example. Last year my friend Mr. C. W. Gilbert, who has conceived it to be his function in life to convert me and to bring the city of Woburn around to what he considers real righteousness in the serving of water, brought in to us a horde of fellows to tell us that we knew nothing, and they demonstrated that to their own satisfaction; the chief among them is my friend Mr. Whitney, your President. For months I sought in vain for an opportunity to get back at him, but a certain article in the Boston *Herald*, just prior to my own inauguration, led me to look into some things in his own city; and I had occasion, to my own satisfaction at least, to even up with him. The particular grievance he has got against us is that we do not have any meters, and we have no use for water meters, and we have never had any lack of water, except to give a banquet to them, such as I have had with you to-day.

I congratulate you on the work that you are doing.

Mr. E. H. Gowing. Mr. President, two months ago I was down in New Orleans and there I met a man whom many of you know, Colonel Gardiner. I have a recollection of a speech that he made in Boston some years ago at a meeting of the American Water Works Association. He wished me when I got back to remember him cordially to all those he knew and who knew him.

Mr. Wm. S. Johnson, assistant engineer, Massachusetts State Board of Health, read a paper entitled "Some New Facts Relating to the Effect of Meters on the Consumption of Water." It was discussed by Messrs. George A. King, Charles W. Sherman, Walter H. Richards, Dexter Brackett, R. J. Thomas, Frank L. Fuller, George Cassell, F. H. Hayes, Henry V. Macksey, J. C. Gilbert, X. H. Goodnough, and Mr. Johnson.

On account of the lateness of the hour the paper by Mr. F. A. Barbour, which had been announced for this meeting, was, with Mr. Barbour's consent, postponed until the September meeting.

The Secretary read applications for membership from the following persons:

William W. Lewis, water commissioner, Hyde Park, Mass.; Samuel W. Hoyt, Jr., resident engineer, Water Filtration Plant, South Norwalk, Conn.; George A. Nelson, assistant city engineer on Water Works, Lowell, Mass.; Howard M. King, assistant engineer, Water Department, Springfield, Mass.; Leland G. Carlton, Springfield, Mass.; Walter Wood, treasurer, engineer, and manager, Millville, N. J., and Owego, N. Y., water companies, Philadelphia, Pa.; S. E. Killam, Reading, Mass.; John C. DeMello, general foreman Distributing Department, New Bedford Water Works, New Bedford, Mass.; David S. Rundlett, superintendent Water Works, Watertown, Mass.; Edward L. Hatch, general manager Stamford Water Company, Stamford, Conn.,

all of whom had been recommended for election by the Executive Committee.

On motion the Secretary was authorized to cast a ballot for the Association in favor of the applicants, which he did, and they were declared elected to membership.

The meeting then adjourned.

EXECUTIVE COMMITTEE.

Boston, Mass.,
March 13, 1907, 11.30 A.M.

Present: President J. C. Whitney, and members George W. Batchelder, L. M. Bancroft, R. J. Thomas, D. N. Tower, George A. King, A. E. Martin, George H. Snell, Charles W. Sherman, and Willard Kent.

Ten applications for membership were received and recommended for admission.

The record of the last meeting of the Executive Committee was read and approved.

Application received and laid on the table at last meeting of the Executive Committee was discussed without action.

Committee on June excursion reported in favor of Gloucester, Mass. Report was accepted and committee continued.

On motion of Mr. Bancroft, seconded by Mr. Snell, the President, Editor, and Secretary were made a Committee on Publicity.

Six members previously dropped for non-payment of dues were by vote reinstated, their dues having been paid in full.

Place of next annual convention was discussed without action.

Voted: That the President and Secretary be a Committee on Hotel Accommodations for the next winter meetings.

Adjourned.

Willard Kent, *Secretary.*

OBITUARY.

Valentine C. Hastings, vice-president of the Association, and superintendent of the Concord, N. H., Water Works, died at his home in that city on March 14, 1907.

He was born in Waterford, Vt., February 26, 1838. In 1867 he entered the employment of the Cement-Lined Water Pipe Co. of Springfield, Mass. In 1869 he took charge of a similar company in Manchester, N. H., and a short time later he went to Concord to superintend the construction of the water works system. In April, 1873, he was elected superintendent of the Concord Water Works, and held that position until his death. His ability and fidelity are attested by the long period of service in this office.

Mr. Hastings had at various times held a number of positions of trust and honor in business and church circles, and was a member of the state legislature in 1887. He leaves a wife, three daughters, and one son. The Concord *Daily Patriot* said of him: "As a good citizen and a man of steadfast friendship he will be greatly missed."

Mr. Hastings was elected a member of this Association on June 10, 1886. He served as one of the vice-presidents several years ago, and was again elected to that office at the last annual meeting.

Myron Edward Evans, C.E., president of the Cape Breton Railway of Canada, was killed in the wreck on the New York Central & Hudson River Railroad at Bronx Park, New York City, on February 16, 1907.

Mr. Evans had an office in New York City and was on his way to his home in White Plains, N. Y., when the accident occurred. He was a graduate of the Rensselaer Polytechnic Institute, Class of 1895, and was an associate member of the American Society of Civil Engineers. He was elected a member of the New England Water Works Association June 13, 1900.

John F. J. Mulhall, water-works accountant and treasurer of several water companies, died on June 9, 1907, following an operation for appendicitis.

Mr. Mulhall was born in Boston on December 3, 1862. He was graduated from the Boston English High School in 1880. His first employment was as clerk in the Boston Railroad Clearing House. Later he studied shorthand under the Hon. Stephen O'Meara, the present police commissioner, then editor of the Boston *Journal*. For some years he was in the office of the Boston Water Board, and in 1885 entered the employ of Wheeler & Parks, engineers and operators of water companies. After the dissolution of that firm Mr. Mulhall remained with Mr. William Wheeler as accountant, and was treasurer of several of the water companies of which Mr. Wheeler is general manager. More recently he had also done private work as an expert accountant. In 1906 he published a book entitled "Quasi-Public Corporation Accounting and Management."

Mr. Mulhall was a member of the Boston Common Council in 1889 and 1890. He is survived by a wife and ten children.

He was elected a member of the New England Water Works Association, November 14, 1900.

BOOK REVIEWS.

The Value of Pure Water. By George C. Whipple. viii + 84 pp. 5½ x 8 inches. New York: John Wiley & Sons. $1.00.

This little book unquestionably fills a long-felt want. It represents an attempt to express in terms of dollars and cents the depreciation suffered by a contaminated or otherwise objectionable water in comparison with one which is absolutely pure and unobjectionable.

As the author says in his preface, "The financial standard is certainly not the highest one for judging the quality of a water supply when the public health is concerned; human life cannot be estimated in gold dollars, and the smell of unsavory water to a thirsty man cannot be reckoned in dimes; nevertheless, the financial basis is a convenient one, and one necessarily involved in all questions which relate to public utilities."

No one is more competent than Mr. Whipple to speak upon this subject with authority, as is well known to the members of this Association. The matter is presented in Mr. Whipple's usual clear and logical style, and is so well presented that it makes a very readable as well as a very valuable book.

Outlines of Practical Sanitation. By Dr. Harvey B. Bashore, Inspector for Pennsylvania Department of Health. vi + 208 pp. 5 x 7½ inches. New York: John Wiley & Sons. $1.25.

This is a very interesting little book for the general reader and contains much valuable sanitary information. One chapter of twenty-five pages is devoted to water supply. This is probably as much space as proportionally belongs to this subject in a book of this size on general sanitation. The importance of sanitary surveys of watersheds is clearly set forth, and the sanitary significance of various substances in or properties of water are well presented.

Water-Works Management and Maintenance. By Winfred D. Hubbard and Wynkoop Kiersted. vi + 429 pp. 6 x 9 inches. Many illustrations. New York: John Wiley & Sons. $4.00.

A book on water-works operation and maintenance has been needed for a long time, and it is therefore a pleasure to welcome this work, which contains a great deal of data not otherwise available except, for the most part, in the Journal of this Association and in engineering periodicals.

The contents are: Part I — On the Methods and Principles of Developing, Improving, and Storing Water Supplies: Ground Water Supply; River-water Supply; Pumping Engines; Impounded Supplies. Part II — Maintenance and Operation: Plans and Records; Extensions; Service Connections; Meters; Care of Appurtenances; Alterations and Repairs; Maintenance of Quality; Water Waste; Electrolysis; Fire Protection; Accounts; Financial Management; Rules and Regulations; Annual Reports. Part III — Franchise: Water Rates; Depreciation.

Part I constitutes 217 pages, or more than half of the volume. It has to do almost wholly with the selection of sources of supply, their development and the filtration or other improvement of unsatisfactory waters, subjects previously treated by several writers, and, moreover, relating to matters of design and construction rather than of maintenance and operation of water works. Although the importance of these subjects is fully conceded and the excellence of their treatment in the present volume is not disputed, it seems to the reviewer that they are out of place in this book, or rather that the space devoted to them should not have exceeded 15 to 20 per cent., instead of 50 per cent., of the book.

Passing to Part II, "Maintenance and Operation," the part which gives the book its reason for existence, it is a pleasure to find so much valuable information, and, on the whole, so well arranged. It is out of the question, within the limits of this review, to give a more detailed statement of what the book contains than is presented in the above table of contents, and it may therefore be well to pass to a mention of what, in the reviewer's opinion, are some of the defects of the book.

In the first place, would it not have been wise to make a handbook or "pocket-book," similar to Trautwine, Kent, and Foster, instead of a book of such shape and bulk as to be convenient for library use only?

Although the paper is good and the type clear and sharp, the make-up may be criticised in several points. First and most important, there are practically no sub-headings, and even after looking up a reference in the index,— which, by the way, is a good one, — there is nothing to catch the eye and assist in finding the place. A freer use of bold-faced type and italics would have much improved the book in this particular. When tables or diagrams which are set lengthwise of the page are examined, it is found that some of them read up and others down. Some of the figures are on so small a scale as to render it difficult, if not impossible, to obtain the information which they are intended to convey — witness the cut of the Walker hydrant. Some of the half-tone cuts were made with so coarse a screen as to seriously impair the effect of the illustrations.

Some of the subjects not mentioned which appear well worthy of treatment are the following:

Forestry of watersheds; screens in intake gate houses; durability of asphalt in reservoir linings; anchor ice; painting; standpipes; ice in standpipes; selection of fuel; electrically-operated valves; hydraulic valves; check valves; valve chambers; fire service meters; the importance of measuring the quantity of water supplied to a distribution system, etc.

In spite of these defects, however, the book is a valuable one, and is certain to prove of much use to water-works men.

TRADE PUBLICATIONS.

Allis-Chalmers Company (Milwaukee, Wis.), *Pumping Engine Department.* Bulletin No. 1609, March, 1907. *Official Duty Tests of Pumping Engines Nos. 1, 2, and 3, at Bissell's Point Pumping Station, St. Louis, Mo., Water Works.* Pp. 25. 8 x 10½ inches. Tables and illustrations.

These pumping engines are each of 20 000 000 gallons capacity, of the vertical triple-expansion type, with outside packed single-acting plungers. The tests were made in 1904 and 1905, and showed duties of 176 866 000, 176 094 000, and 181 068 605 foot-pounds, respectively, per 1 000 pounds of steam. The results of the tests are given in detail in the bulletin.

Cast-Iron Pipe. *Some Notes and Tables. Standard Specifications, Dimensions, and Weights of Cast-Iron Bell and Spigot Pipe and Special Castings for Water, Gas, Sewages, Culverts, Drains, etc. Flange Pipe and Special Castings, Flexible Joint Pipe, Loam Castings, Heavy Special Castings.* 1906. New York: United States Cast Iron Pipe and Foundry Company. Pp. 156. 8¾ x 10¾ inches.

This excellent handbook or catalogue contains considerable historical and descriptive matter relating to water conduits, especially cast-iron pipe, with many good illustrations. The standard specifications of the company are given. It is stated that " the standard specifications for cast-iron pipe and special castings will be found to be substantially those of the New England Water Works Association, modified to cover the four classes of pipe shown in our Table No. 2 instead of the ten classes listed in Table No. 2 of the New England specifications, while many of the dimensions in our Table No. 1 are identical with those of the New England Table No. 1." The greater part of the book is devoted to tables of dimensions and weights and other particulars relating to pipes and special castings, data which would be indispensable to any one laying out details of piping to be constructed with these standard castings.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXI. September, 1907. No. 3.

WATER-WORKS STATISTICS FOR THE YEAR 1906, IN FORM ADOPTED BY THE NEW ENGLAND WATER WORKS ASSOCIATION.

COMPILED BY CHARLES W. SHERMAN, EDITOR, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

The tables presented herewith contain statistics of forty-three water works, as summarized in their annual reports. These are all municipally owned water works. There are other water works which summarize their statistics, but the compiler has not succeeded in obtaining their reports for the year 1906.

The report of the Committee on Uniform Statistics, containing the form as endorsed for use in the 1901 reports, is printed on page 51 of Vol. XV of the JOURNAL (March, 1902). The page for Financial Statistics was changed by vote of the Association in September, 1902, as reported in the December, 1902, JOURNAL (Vol. XVI, p. 263). Blank forms for use in preparing summaries are printed by the Association, and will be furnished on request.

Previous compilations of statistics may be found in the JOURNAL, as follows:

Statistics for	Reference to Journal.
1886	Vol. I, No. 4, p. 29
1887	Vol. II, No. 4, p. 28
1888 to 1892 inclusive	Vol. VII, p. 225
1893	Vol. IX, p. 127
1894	Vol. X, p. 131
1895–96	Vol. XII, p. 273
1897–99	Vol. XV, p. 65

Statistics for	Reference to Journal.
1900	Vol. XV, p. 367
1901	Vol. XVI, p. 223
1902	Vol. XVII, p. 235
1903	Vol. XVIII, p. 277
1904	Vol. XIX, p. 241

In the various tabulations, statistics are given for the following places and years:

Place.	Year.
Albany, N. Y.	1900
Andover, Mass.	1900
Arlington, Mass.	1900, 1904, 1906
Atlantic City, N. J.	1898, 1900–04
Attleboro, Mass.	1894–1904, 1906
Bay City, Mich.	1886–87, 1893–96, 1900–04
Belmont, Mass.	1902–04, 1906
Beverly, Mass.	1903, 1906
Billerica, Mass.	1899–1904, 1906
Boston, Mass.	1886–94, 1897, 1900, 1903
Bridgeport, Conn.	1904
Brockton, Mass.	1893–1904, 1906
Burlington, Vt.	1886–1904, 1906
Cambridge, Mass.	1900–04, 1906
Chelsea, Mass.	1900–04, 1906
Cleveland, Ohio	1902–04, 1906
Concord, N. H.	1895, 1898, 1900–04
Dover, N. H.	1900
Erie, Pa.	1900
Essex Junction, Vt.	1900
Fall River, Mass.	1886–95, 1897–1904, 1906
Fitchburg, Mass.	1886–92, 1894–1904, 1906
Freeport, Me.	1901
Geneva, N. Y.	1900
Gloucester, Mass.	1906
Harrisburg, Pa.	1906
Haverhill, Mass.	1900, 1904, 1906
Holyoke, Mass.	1886–92, 1897–98, 1900–04, 1906
Hull, England	1900
Ipswich, Mass.	1900
Keene, N. H.	1899–1900, 1903–04
Lawrence, Mass.	1902–04
Leicester, Mass.	1900
Leominster, Mass.	1900
Lewiston, Me.	1900

Place.	Year.
Lowell, Mass.	1886, 1897–1904, 1906
Lynn, Mass.	1888–98, 1900–04, 1906
Madison, Wis.	1900, 1902–04, 1906
Manchester, N. H.	1900
Marlborough, Mass.	1900, 1903–04, 1906
Maynard, Mass.	1901–03
Metropolitan Water Works, Mass.	1900–04, 1906
Middleboro, Mass.	1895–1904, 1906
Middletown, Conn.	1902
Minneapolis, Minn.	1900–04, 1906
Nantucket, Mass.	1900
Nashua, N. H.	1900, 1904
New Bedford, Mass.	1886–1904, 1906
New London, Conn.	1886–1904, 1906
Newton, Mass.	1888–1904, 1906
Norwich, Conn.	1901
Oberlin, Ohio	1893–1904, 1906
Plymouth, Mass.	1886–1904, 1906
Providence, R. I.	1897–1904, 1906
Quincy, Mass.	1893, 1900–01
Reading, Mass.	1893, 1895–1904, 1906
Reading, Pa.	1901–04, 1906
Rochester, N. Y.	1903
St. John, N. B.	1902–03
Salem, Mass.	1900
Sandusky, Ohio	1886
Schenectady, N. Y.	1886, 1900–01
Somerville, Mass.	1900–04, 1906
Springfield, Mass.	1886–1904, 1906
Taunton, Mass.	1886–1904, 1906
Toronto, Canada	1893
Trenton, N. J.	1886–87
Troy, N. Y.	1886, 1888–93, 1897–99
Waltham, Mass.	1886–1904, 1906
Ware, Mass.	1886, 1888–92, 1900–04, 1906
Watertown, Mass.	1900
Wellesley, Mass.	1888–93, 1898–1904, 1906
Westerly, R. I.	1902–04, 1906
Whitman, Mass.	1897–1904, 1906
Wilmington, Del.	1900
Winchendon, Mass.	1900–04, 1906
Woburn, Mass.	1900–04
Woonsocket, R. I.	1886–1900, 1902–04, 1906
Worcester, Mass.	1900, 1906
Yonkers, N. Y.	1893–96, 1900–04, 1906

1906. — TABLE 1. — GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply	1 Builders of pumping machinery.	2. — Description of fuel used. a Kind.	b Brand of coal.	c Av. price per gross ton.	d Per cent. of ash.	e Wood. Price per cord.
1	Arlington, Mass.	1872 1894	Town.	Metropolitan W.W.	....	....	....	....	....	..	....
2	Attleboro, Mass.	1873	Town.	Well.	Pumping.	Deane, Barr.	Bituminous.	Georges Cr.	....	..	....
3	Belmont, Mass.	1887	Town.	Metropolitan W.W.	....	....	....	....	....	..	....
4	Beverly, Mass.	1869 1886	City.	Wenham Lake, Longham Res.	Pumping.	Holly.	Bituminous.	Georges Cr.	$3 74	11.2	....
5	Billerica, Mass.	1898	Town.	Driven Wells.	Pumping.	Barr.	Bituminous.	New River.	4 85	..	....
6	Brockton, Mass.	1880 1902	City.	Silver Lake.	Pumping.	Barr.	Bituminous.	New River.	4 90	10.6	....
7	Burlington, Vt.	1867	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.	....	3 50	..	....
8	Cambridge, Mass.	1855	City.	HobbsBrook, Stony Brook, Fresh Pond.	Pumping.	Groshon, Worthington, Blake.	Bituminous.	Quemahoning Orenda.	3 70 4 00 4 30	.. .. ..	....
9	Chelsea, Mass.	1867	City.	Metropolitan W.W.	....	....	....	....	....	..	....
10	Cleveland, Ohio.	1856	City.	Lake Erie.	Pumping.	Worthington, Knowles, Allis, Kilby, Holly.	Bituminous.	Pittsburg Slack.	1 85	..	....
11	Fall River, Mass.	1874	City.	N. Watuppa Lake.	Pumping.	Worthington, Davidson.	Bituminous.	Cumberland, Georges Cr.	....	..	....
12	Fitchburg, Mass.	1873	City.	Storage Reservoirs.	Gravity.	....	....	....	....	..	....
13	Gloucester, Mass.	1884	City.	Reservoirs.	Pumping.	Knowles, Barr.	Bituminous.	Georges Cr.	5 00	8.5	....
14	Harrisburg, Pa.	1843	City.	Susquehanna R. (filtered).	Pumping.	Barr, Harrisburg.	Anthracite.	Pea.	1 25	17	....

15	Haverhill, Mass.	..	City.	Ponds.	Gravity and Pumping.	Worthington, Deane, Barr.	Bituminous.	Cumberland, Carbon.	$5 16	10	....
16	Holyoke, Mass.	1873	City.	Lakes and Res'v's.	Gravity.	....	....	....	....	..	....
17	Lowell, Mass.	1870	City.	Driven Wells.	Pumping.	Morris, Worthington, Deane, Knowles.	Bituminous.	Pocahontas, Argyle, New River.	5 02	..	....
18	Lynn, Mass.	1871	City.	Ponds and River.	Pumping.	Leavitt, Loretz.	Bituminous.	Georges Cr.	....	13.1	....
19	Madison, Wis.	1882	City.	Artesian Wells.	Pumping.	Allis-Chalmers, Knowles.	Anthracite.	Pea.	4 52	..	....
20	Marlboro, Mass.	1883	City.	Lake and Res.	Pumping.	Blake, Worthington, Barr.	Bituminous.	Various.	5 05	..	....
						Chestnut	*Hill High*	*Service Stat'n*			
						Holly, Quint'd Allis.	Bituminous.	Quemahoning Orenda, Georges Cr., Cumberland, Peerless, Miller V., Vulcan, Carbon.	4 09 to 4 79	11.9	....
21	Metropolitan Water Works, Mass.	1848 1872 1895	State of Massachusetts.	L. Cochituate, Sudbury River, Nashua River.	Pumping, 73%. Gravity, 27%.		Anthracite.	Buckwheat, Screenings.	2 93 2 52		
						Chestnut Hill	*Low Service*	*Station.*			
						Holly.	Bituminous.	Quemahoning Orenda, Carbon.	4 00 to 4 42	13.4	....
							Anthracite.	Buckwheat, Screenings.	2 84 2 52		
						Spot	*Pond*	*Station.*			
						Blake, Holly.	Bituminous.	Georges Cr., Cumberland.	4 35 to 4 38	12.9	....
							Anthracite.	Screenings.	2 24		
22	Middleboro, Mass.	1885	Fire Dist.	Well.	Pumping.	Deane.	Bituminous.	Pocahontas.	4 58	..	....
23	Minneapolis, Minn.	1868	City.	Mississippi River.	Pumping.	Worthington, Holly.	Sawdust and edgings. Coal.	....	3 27	..	$1 35

1906.—TABLE 1, *Continued.*—GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply.	1. Builders of pumping machinery.	2.—Description of fuel used. a. Kind.	b. Brand of coal.	c. Av. price per gross ton.	d. Per cent. of ash.	e. Wood. Price per cord.
24	New Bedford, Mass.	1866	City.	Ponds.	Pumping.	Dickson.	Bituminous.	Georges Cr. Pocahontas.	$4 61 4 64	7	....
25	New London, Conn.	1872	City.	Lake and Res.	Gravity and Pumping.	....	....	....	....	..	....
26	Newton, Mass.	1876	City.	Collecting Gallery.	Pumping.	Barr, Worthington.	Bituminous. Anthracite.	Georges Cr., New River. Screenings.	4 20	14	$6 00
27	Oberlin, Ohio.	1887	Village.	E. Br., Vermillion R.	Pumping.	Deane.	Bituminous.	Pocahontas.	4 10	..	....
28	Plymouth, Mass.	1855	Town.	Ponds.	Gravity and Pumping.	Barr, Worthington.	Bituminous.	Various.	5 00	..	....
29	Providence, R. I.	1870	City.	Pawtuxet River. (filtered.)	Pumping.	Allis-Chalmers. Worthington. Corliss. Holly. Nagle.	Bituminous. Bituminous. Bituminous. Anthracite. Anthracite.	New River. New River. New River. Buckwheat. Buckwheat.	4 17 4 17 4 17 3 23 3 23	8.9 7.3 11.4 20.0 16.2	4 50 4 50 4 50 3 50 3 50
30	Reading, Mass.	1891	Town.	Filter Gallery.	Pumping.	Blake.	Bituminous.	Carbon Fge.	5 70	..	....
31	Reading, Pa.	1819	City.	Creeks and Springs.	Gravity and Pumping.	Worthington, Allis-Chalmers.	Bituminous.	....	2 63	9.4	3 50
32	Somerville, Mass.	1868	City.	Metropolitan W.W.	....	....	....	....	....	..	....
33	Springfield, Mass.	1864	City.	Reservoirs.	Gravity.	....	....	....	....	..	....
34	Taunton, Mass.	1876	City.	Ponds.	Pumping.	Holly, Allis.	Bituminous.	Georges Cr. Cumberland.	5 15 4 50 & 4 65	..	....

35	Waltham, Mass.	1872	City.	Filter Basin.	Pumping.	Barr, Worthington.	Bituminous. Anthracite.	Pocahontas, Screenings.	$5 25	12.5	....
36	Ware, Mass.	1886	Town.	Wells.	Pumping.	Deane, Warren.	Bituminous.	....	5 00	..	$4 50
37	Wellesley, Mass.	1884	Town.	Wells.	Pumping.	Blake.	Bituminous.	Georges Cr., Cumberland.	4 63	9.0	3 50
38	Westerly, R. I.	1886	Town.	Driven Wells.	Pumping.	Worthington.	Bituminous.	Georges Cr.	4 84	..	6 00
39	Whitman, Mass.	1883	Town.	Brockton W. W.[1]	Pumping.	....	....	....	....	..	....
40	Winchendon, Mass.	1896	Town.	Well.	Pumping.	Blake.	Bituminous.	....	5 02	14.9	....
41	Woonsocket, R. I.	1884	City.	Crook Fall Brook.	Pumping.	Worthington, Deane, Builders I. Fdy.	Bituminous.	Pocahontas.	5 28	8.3	3 00
42	Worcester, Mass.	1845	City.	Reservoirs.	Gravity.	....	....	....	....	..	....
43	Yonkers, N. Y.	1876	City.	Brooks, Rivers, and Wells.	Pumping.	Wright, Worthington, Wood.	Bituminous.	Georges Cr.	4 10	10.8	12 00

[1] See Brockton.

1906.—TABLE 1, *Concluded*.—PUMPING STATISTICS.

	3	4	4a	5	6	7	8	9	10	11	12
Number.	Coal consumed for the year. (Lbs.)	Lbs. of wood ÷ 3 = equivalent coal.	Amount of other fuel used.	Total equivalent coal consumed for the year. (Lbs.) (3) + (4).	Total pumpage for the year in gallons.	Average static head against which pumps work. (Feet.)	Averaged dynamic head against which pumps work. (Feet.)	Number of gallons pumped per lb. of equivalent coal.	Duty in foot-pounds per 100 pounds of coal. No deductions.	Cost per million gallons pumped into reservoir, figured on pumping station expenses.	Cost per million gallons raised 1 foot high, figured on pumping station expenses.
2	609 321	.....	....	....	223 793 920	...	188	367	72 955 200	......	......
							225				
4	1 040 557	.....	....	....	519 152 436[1]	126	146	496	60 789 667	$17 56	$0 12
5	308 311	.....	....	....	30 763 788[1]	290	318	100	26 419 693	65 84	0 21
6	1 772 279	.....	....	1 772 279	674 914 949[1]	202	288	381	91 469 329	11 64	0 04
7	2 864 600	.....	....	....	368 257 775[1]	289	316	129	33 237 044	23 02	0 07
8	4 316 255	500	....	4 316 755	3 386 180 600[1]	158	194	784	127 205 058	5 86	0 03
10	46 722 200[a]	.....	....	46 722 200[a]	21 552 886 258[1a]	171[a]	202[a]	461[a]	77 870 010[a]	4 21	0 02
11	2 139T	.....	....	....	1 634 300 539	...	185	341	....	10 52	......
13	893 659	.....	....	893 659	454 843 889[1]	117	140	509	59 427 110	12 24	0 09
14	11 994 858	.....	....	....	3 803 869 700[1]	200	235	321	65 132 042	5 33	0 02
15	1 955 678	.....	....	1 955 678	1 060 562 257[2]	190	203	730	91 812 308	12 01	0 06
								242			
17	7 904 865	2 400	....	7 907 265	1 855 043 406	156	164	235	62 941 506	20 60	0 13
19	1 835 100	.....	....	....	522 648 000[1]	201	231	...	....	......	......
20	622 900	.....	....	....	202 340 250[2]	172	174	318	47 138 879	12 99	0 07
*21a	3 014 777	.....	....	....	1 905 110 000[2]	...	121	632	65 670 000	6 64	0 06
b	518 933	.....	....	....	514 220 000[2]	...	128	991	114 550 000	3 50	0 03
c	8 518 537	.....	....	....	10 310 810 000[2]	...	132	1 210	136 740 000	2 91	0 02
d	7 955 358	.....	....	....	18 938 590 000[2]	...	51	2 381	104 520 000	1 69	0 03
e	2 533 049	.....	....	....	3 031 770 000[2]	...	128	1 197	131 600 000	4 03	0 03
22	638 510	.....	....	638 510	112 318 000[1]	182	204	176	29 928 012	......	......
23	9 811 025	.....	....	....	6 426 708 815	218	237	...	71 300 000 to	......	......
									89 400 000		
24	2 879 165	.....	....	2 879 165	2 493 186 540[2]	168	185	865	133 309 911	6 31	0 03
26	2 092 000	4 000	....	2 096 000	811 927 159[1]	235	262	387	84 643 400	11 65	0 04
27	555 900	.....	....	555 900	71 800 000[2]	80	84	111	9 050 000	34 68	0 40
28	442 140	.....	....	....	214 305 800	65	83	475	32 000 000	16 46	0 20
29	5 346 050	333	....	5 346 383	5 169 354 626[2]	171	180	967	144 947 660		
	682 800	.....	....	682 800	368 533 660[2]	170	174	540	78 545 307	L. S.	L. S.
	120 600	.....	....	120 600	81 354 806[2]	172	181	675	101 673 593	5 40	0 03
	1 524 518	911	....	1 525 429	614 370 545[2]	121	131	403	43 911 603	H. S.	H. S.
	26 766	70	....	26 836	10 665 717[2]	120	127	397	42 112 692	15 70	0 11

30	463 076	.....	....	....	53 551 083[2]	219	240	116	23 125 329	$47 26	$0 20
31	5 411 600	1 800	0	5 413 400	2 135 257 590[1]	213	292	394	96 089 905	6 12	0 02
34	489 900	.....	....	....	624 296 554	...	...	...	....	11 60	......
	1 377 300				698 149 375						
35	1 348 870	.....	....	....	705 360 048[1]	164	180	530	90 140 773	10 25	0 06
36	650 314	700	....	651 014	128 538 540[1]	221	244	197	40 178 980	28 50	0 12
37	616 472	300	....	616 772	99 481 861	260	280	161	37 646 000	29 63	1 05
38	1 504 600	500	0	1 505 100	264 982 500[2]	195	210	176	30 834 200	23 33	0 11
40	318 992	.....	....	....	40 305 620	246	289	148	36 349 966	28 33	0 10
41	1 472 850	607	....	1 473 457	446 894 141[2]	238	239	303	60 477 615	15 43	0 06
43	8 700 009	.....	....	8 700 009	2 543 288 786[1]	185	210	358	66 254 081	10 61	0 05
							222	264	46 562 747		

[1] Without allowance for slip.
[2] With allowance for slip.
a. Kirtland Street Station.

* 21*a*. C. H. H. S. Station, engines 1 and 2.
b. C. H. H. S. Station, engine 3.
c. C. H. H. S. Station, engine 4.
d. C. H. L. S. Station, engines 5, 6, and 7.
e. Spot Pond Station, engine 9.

1906. — TABLE 2. — FINANCIAL STATISTICS.

Number.	Name of city or town.	Receipts.						
		Balance brought forward.		Water rates.			Municipal departments.	
		a From ordinary receipts.	b From extraordinary receipts.	A Fixture rates.	B Meter rates.	C Total from consumers.	D For hydrants.	E For fountains.
1	Arlington, Mass.	$9 672 88	....	$24 538 38	$14 438 01	$38 976 39	....	......
2	Attleboro, Mass.	....	$35 945 20	....	....	35 373 28	....	......
3	Belmont, Mass.	92 36	247 12	....	14 824 29	....	....	......
4	Beverly, Mass.	353 23	....	39 284 29	15 922 58	55 206 87	....	......
5	Billerica, Mass.	....	....	1 100 20	2 692 94	3 793 14	$2 300 00	......
6	Brockton, Mass.	....	21 742 44	3 149 17	97 965 34	101 114 51	....	......
7	Burlington, Vt.	45 111 42	947 41	6 641 81	38 920 17	45 561 98	620 00	$617 69
8	Cambridge, Mass.	....	....	....	....	357 280 19	....	......
9	Chelsea, Mass.	....	....	83 390 24	47 215 17	130 605 41	....	......
11	Fall River, Mass.	33 424 25	....	2 419 69	186 749 92	....	....	......
12	Fitchburg, Mass.	....	....	15 326 12	57 685 39	....	....	......
13	Gloucester, Mass.	14 56	5 43	65 576 50	18 944 86	84 521 36	....	......
14	Harrisburg, Pa.	....	....	34 340 38	140 544 11	174 884 59	....	......
15	Haverhill, Mass.	36 685 84	....	79 131 64	28 305 31	107 436 95	....	......
16	Holyoke, Mass.	3 865 25	....	86 522 97	31 000 29	117 523 26	....	......
17	Lowell, Mass.	31 791 82	....	28 816 73	150 373 42	179 190 15	....	......
18	Lynn, Mass.	....	1 988 22	113 684 29	130 702 29	244 386 58	....	......
19	Madison, Wis.	9 893 04	....	....	....	31 263 33	....	......

20	Marlboro, Mass.	$603 80	....	$10 829 41	$26 553 15	$37 382 56	$6 700 00	......
22	Middleboro, Mass.	1 007 71	....	3 407 54	7 454 23	10 861 77	....	......
23	Minneapolis, Minn.	....	....	53 943 96	200 911 49	254 855 54	....	......
24	New Bedford, Mass.	37 316 64	$14 122 75	78 838 23	120 568 09	199 406 32	....	......
25	New London, Conn.	79 507 62	....	....	....	66 389 86	12 840 00[1]	$300 00[1]
26	Newton, Mass.	....	....	2 157 00	120 325 00	122 482 00	....	......
27	Oberlin, Ohio	....	....	894 25	10 767 75	11 662 00	....	......
28	Plymouth, Mass.	....	849 42	....	....	29 260 19	....	......
30	Reading, Mass.	28 19	....	....	11 047 52	11 047 52	4 950 00	300 00
31	Reading, Pa.	19 218 46	....	157 368 79	53 430 52	210 799 31	....	......
32	Somerville, Mass.	....	....	133 886 92	92 533 42	226 420 34	....	......
33	Springfield, Mass.	19 249 10	....	141 609 52	118 577 47	260 186 99	26 850 00[1]	670 00[1]
34	Taunton, Mass.	....	3 353 53	....	....	71 236 11	....	......
35	Waltham, Mass.	5 651 09	60 760 07	59 180 57	15 490 75	74 671 32	....	......
36	Ware, Mass.	3 360 39	191 26	....	9 173 86	10 503 87	....	171 45
37	Wellesley, Mass.	4 768 82	513 90	240 00	15 832 69	16 072 69	3 500 00[2]	......
38	Westerly, R. I.	12 061 66	....	2 787 38	27 611 60	30 398 98	3 208 32	......
39	Whitman, Mass.	17 80	....	2 700 25	6 578 71	....	2 920 00	......
40	Winchendon, Mass.	917 55	....	76 40	7 159 89	7 236 29	4 680 00	313 96
41	Woonsocket, R. I.	....	....	2 470 70	68 078 54	70 549 24	17 875 00	2 170 64
43	Yonkers, N. Y.	....	45 899 60	....	....	160 198 15	30 990 00	......

[1] Book account only.

[2] Includes fountains and street watering.

Number	Municipal departments — Continued. F For street watering.	G For public buildings.	H For miscellaneous uses.	I General appropriation.	J Total from municipal departments.	K From tax levy.	L From bond issue.	M From other sources.	N Total receipts.
1	....	....	....	$7 000 00	....	....	$835 41	....	....
2	....	....	....	1 000 00	....	....	....	$7 295 43	....
3	....	....	....	1 000 00	....	....	5 500 00	926 37	$22 343 02
5	....	....	....	937 09	....	....	....	57 04 149 32	....
6	$1 000 00	....	....	....	$1 000 00	....	45 000 00	60 329 59	229 186 54
7	1 687 12	$207 26	$45 111 42	....	....	....	....	947 41	....
8	....	....	....	....	....	....	....	5 961 77 3 627 24	366 869 20
9	....	....	....	....	....	$10 000 00	....	1 762 79	142 368 20
11	....	....	....	....	....	....	....	409 02 3 360 93	226 363 81
12	....	....	....	....	....	....	....	6 574 37	79 585 88
13	....	....	....	7 786 00	7 786 00	....	30 000 00	2 828 92	139 701 71
14	....	....	....	....	....	....	....	7 386 44	182 271 08
15	....	....	....	....	....	....	....	9 450 07	153 572 86
16	....	....	....	....	....	....	....	5 684 90	127 073 41
17	1 500 00	4 650 40	....	....	6 150 40	17 800 00	27 000 00	26 115 39	288 047 76
18	....	....	....	....	....	....	....	16 009 61	262 384 41
19	....	....	....	....	....	10 000 00	....	4 705 42	55 861 79
20	....	227 27	5 40	....	6 992 67	....	....	2 623 76	47 602 69

22	....	....	....	....	$1 500 00	....	....	$1 360 93	$14 730 41
23	....	....	....	....	....	$78 163 53	....	?	360 224 92
24	....	....	....	....	....	....	....	....	250 845 71
25	$1 500 00[1]	$1 500 00[1]	....	....	16 140 00[1]	....	....	....	163 144 99
26	3 000 00	2 681 00	....	....	5 681 00	....	$5 028 47	9 286 00 36 995 51 358 10	....
27	....	....	$456 88	....	456 88	3 076 95	....		15 553 93
28	....	....	....	....	....	....	....	3 563 29	....
30	500 00	....	....	....	5 750 00	....	....	843 01	17 668 72
31	....	....	....	....	0	....	....	14 571 24	244 589 01
32	....	....	....	....	....	....	....	7 880 11	234 300 45
33	6 627 45[1]	13 509 59[1]	4 503 65[1]	....	52 160 69[1]	....	....	27 442 55	359 039 33
34	....	808 50	....	....	....	10 000 00	....	3 619 00 1 250 51 3 608 30	....
35	....	....	1 820 60	....	1 820 60	....	40 000 00		186 511 38
36	....	37 00	365 29	....	573 74	2 700 00	....	229 25	....
37	....	263 34	....	....	3 763 34	....	5 066 67	1 586 30 416 48 2 896 38	32 188 20
38	....	....	....	....	3 208 32	....	....		48 565 34
39	110 22	....	....	$2 500 00	....	800 00	....	3 269 31	18 896 28
40	203 10	....	....	....	5 197 60	8 000 00	....	40 98	21 391 88
41	2 079 36	1 537 58	812 07	39 000 00	63 474 66	....	....	3 719 21	137 743 11
43	....	....	....	....	....	....	180 718 50	6 883 89	....

[1] Book account only.

1906.—TABLE 2, *Continued.*—FINANCIAL STATISTICS.

Number.	Maintenance Expenditures. AA Operation.	BB Special.	CC Total mainte-nance.	DD Interest on bonds.	EE Payment of bonds.	FF Sinking fund.	Construction Expenditures. GG Extension of mains.	HH Extension of services.	II Extension of meters.	JJ Special.	KK Total constr'tion.
1	$4 226 57	$13 663 78[1]	......	$12 960 00	......	$13 000 00	$835 41	$1 016 88	$2 887 66	......	....
2	....	....	$11 578 28	18 295 00	......	6 500 00	......	.....	.....	......	$33 260 62
3	2 134 87	5 668 67[1]	......	1 370 00	$3 250 00	520 00	2 565 11	1 003 37	941 66	$1 182 57	5 692 71
4	20 430 89	....	20 430 89	....	......	....	7 360 02	3 076 31	1 022 05	724 81	12 183 19
5	....	....	4 011 67	3 600 00	......	....	......	106 85	32 05	73 33	212 23
6	38 115 37	....	38 115 37	56 547 50	50 000 00	7 866 14	44 483 18	7 019 62	5 659 90	2 641 56	59 804 26
7	22 664 36	....	......	8 720 00	60 000 00	14 674 47	279 08	674 93	1 083 56	......	1 370 52
8	....	....	68 851 32	143 827 75	12 500 00	123 247 50	......	.....	394 77	......	318 460 76
9	12 387 74	57 687 81[1]	70 075 55	12 000 00	......	5 410 00	......	.....	3 636 74	......	8 655 14
11	....	....	47 595 87	67 910 00	......	....	17 642 99	.....	.....	23 781 19	....
13	23 007 55	....	23 007 55	41 600 00	45 000 00	....	3 835 66	5 923 51	.....	8 838 00 4 215 61	22 812 78
14	61 474 84	14 405 61	95 880 45	34 552 00	......	40 632 63	......	.....	.....	......	....
15	25 136 77	....	25 136 77	39 240 00	5 000 00	18 000 00	5 913 76	5 460 68	682 08	14 571 01	26 627 53
16	42 969 94	4 991 34	7 961 28	13 750 00	......	32 020 24	9 532 96	.....	2 246 40	16 151 00	27 930 36
17	109 294 73	....	109 294 73	45 668 00	16 600 00	17 800 00	34 432 72	8 443 95	.....	......	42 876 67
18	....	....	117 389 78	68 740 00	......	64 000 00	......	.....	.....	......	4 972 30
19	....	....	20 309 79	....	......	5 000 00(?)	......	.....	.....	......	23 786 99
20	9 368 25	....	9 368 25	20 760 00	......	....	......	.....	.....	......	2 682 96

22	$6 643 49	....	$6 643 49	$1 700 00	.....	$2 500 00	$3 104 26	$473 65	$190 80	......	$3 768 71
23	....	....	138 729 86	......	.....	....	......	.....	.....	......	166 992 27
24	40 562 72	....	40 562 72	68 880 00	$30 000 00	28 000 00	20 218 38	5 698 03	4 066 16	$9 536 44	39 519 01
25	10 276 37	....	10 276 37	21 915 35	.....	....	10 354 87	3 456 94	1 084 35	5 939 10	20 835 26
26	25 087 00	....	......	66 190 00	.....	....	17 750 60	11 610 61	3 677 80	8 984 97	42 023 98
27	4 976 52	$797 24	5 773 76	1 100 94	4 000 00	....	353 14	316 74	1 396 02	2 174 40	4 240 30
28	....	....	10 767 52	4 847 36	9 666 66	....	3 344 09	520 45	.....	9 630 12	13 494 66
30	6 268 83	....	6 268 83	8 105 00	.....	....	887 59	1 580 57	656 79	160 61	3 285 56
31	53 679 35	1 438 68	55 118 03	16 132 00	.....	51 500 00	16 068 03	1 675 83	3 327 59	43 450 87	84 522 32
32	27 946 76	97 160 08[1]	......	3 935 00	16 000 00	....	8 136 78	4 724 12	6 334 96	......	19 195 86
33	39 334 72	3 150 01 15 372 81	54 707 53	21 875 00	.....	....	24 054 14	.....	.....	755 02 61 857 87	85 156 99
34	30 734 89	....	......	34 195 00	.....	....	5 456 31	3 006 93	1 702 83	3 400 00	13 566 07
35	38 043 37	5 000 00	43 043 37	18 910 00	.....	14 000 00	3 464 84	4 875 60	160 00	29 771 80	38 272 24
36	7 436 71	....	......	1 065 00	2 700 00	....	......	.....	.....	......	1 878 83
37	7 156 00	....	......	11 320 00	.....	....	6 158 83	946 04	.....	......	....
38	10 015 42	....	10 015 42	13 361 70	.....	7 500 00	1 825 25	1 971 88	1 056 01	550 00	5 403 14
39	2 213 54	4 181 80[2]	6 395 34	4 800 00	.....	2 007 55 2 500 00	......	.....	.....	......	3 157 52
40	3 792 94	....	......	3 400 00	3 000 00	....	2 495 90	473 60	409 42	7 104 65	10 483 57
41	16 782 30	....	......	......	.....	....	......	.....	.....	......	24 917 21
43	....	....	87 924 07	86 783 33	.....	27 000 00	......	.....	.....	......	105 560 68

[1] Metropolitan water-works assessment.

[2] Paid city of Brockton for water and pumping.

1906. — TABLE 2, *Concluded.* — FINANCIAL STATISTICS.

Number.	LL	MM Balance.		N		O	P	Q	R
	Unclassified expenses.	aa Ordinary.	bb Extraordinary.	Total.	Disposition of balance.	Net cost of works to date.	Bonded debt at date.	Value of sinking fund.	Average rate of interest. Per cent.
1	....	$9 283 25	....	....	....	$511 771 00	$326 000 00	....	4
2	....	....	$9 980 01	....	....	629 781 51	487 000 00	$40 526 70	.....
3	....	2 031 57	1 428 08	$22 343 02	....	....	38 250 00	5 820 02	4
4	$38 720 72	....	....	71 334 80	....	507 737 82	....	....	.....
5	....	—524 40	—62 91	....	....	92 490 23	....	....	.....
6	4 567 50	....	12 285 77	229 186 54	Forward.	1 713 251 95	1 485 000 00	523 065 53	3.6
7	....	....	....	....	....	491 446 59	188 000 00	14 674 47	4
8	4 710 37	....	....	....	....	6 342 200 46	3 383 600 00	1 509 749 85	3½–4
9	639 20	....	6 363 26	....	City Treasury.	507 580 57	300 000 00	110 824 00	4
11	....	69 433 76	....	226 363 81	....	2 076 499 40	1 550 000 00	530 768 51	3.99
12	45 212 66	34 373 22	....	79 585 88	City Treasury.	446 043 90	532 000 00	85 956 10	.....
13	6 683 39	482 99	115 00	139 701 71	....	1 386 358 50	1 143 000 00	....	3½ and 4
14	3 713 00	27 493 00	....	182 271 08	General Fund.	1 250 000 00	921 600 00	265 560 00	3½
15	26 464 77[1]	39 568 56	....	153 572 86	....	1 432 807 88	976 000 00	295 057 54	4
16	2 822 31	2 589 22	....	....	....	1 296 773 85	350 000 00	86 687 42	.....
17	13 355 81	25 101 61	17 350 94	288 047 76	Forward.	3 054 082 82	1 085 400 00	473 908 75	4
18	5 945 47	....	1 336 86	262 384 41	Const.	2 966 713 22	1 788 500 00	453 262 36	3¾
19	....	6 765 01	....	55 861 79	....	477 011 46	32 500 00	....	3¾ and 4

20	....	$14 791 48	....	$47 602 69	....	$592 170 84	$519 000 00	$233 149 45	4
22	....	118 21	....	14 730 41	....	121 962 80	39 000 00	13 068 11	4
23	....	....	....	....	....	....	1 930 000 00	....	.....
24	....	43 883 98	....	250 845 71	Forward.	3 332 753 27	1 578 000 00	367 538 48	4.28
25	$30 000 00[2]	80 118 01	....	163 144 99	....	1 019 340 86	601 000 00	....	3.6
26	....	46 172 00	....	....	....	2 232 446 00	1 387 000 00	494 911 00	4
27	146 67	292 26	....	15 553 93	....	118 277 77	43 000 00	918 12	3.5
28	....	....	—$5 103 30	....	....	379 758 21	119 999 82	....	3½ to 4
29	....	....	....	....	....	7 228 867 84	433 000 00	382 080 02	3½
30	....	9 33	....	17 668 72	Forward.	....	201 000 00	0	4
31	5 000 00[3]	32 316 66	....	244 589 01	Forward.	2 908 028 24	400 000 00	94 844 49	4
32	5 10	66 907 64	....	234 300 45	City Treasury.	874 698 99	86 000 00	....	4
33	52 022 52[3] 22 201 92	100 875 96 22 199 41[4]	....	359 039 33	Sinking Fund.	2 399 480 66	555 000 00	151 255 09	3.81
34	....	7 556 73	3 406 46	....	Sinking Fund.	1 347 106 32	838 500 60	326 595 77	3½ and 4
35	....	1 138 34	71 147 43	186 511 38	....	671 852 57	543 000 00	258 390 93	3.90
36	....	4 365 54	112 43	....	....	143 643 86	27 900 00	....	3½ and 4
37	72 57 1 703 94[2]	4 768 82	62 00	32 188 20	....	348 245 26	287 000 00	145 805 85	4
38	....	12 285 08	....	48 565 34	Forward.	375 296 80	353 000 00	67 413 27	3¾
39	....	35 87	....	18 896 28	....	165 674 03	120 000 00	....	4
40	....	715 37	....	21 391 88	....	142 205 27	82 000 00	....	4
41	....	....	96 043 60	137 743 11	....	258 304 54	1 032 000 00	154 540 35	3.8
43	....	....	29 258 22	....	....	2 189 040 07	1 895 000 00	304 378 92	5.33

[1] Depreciation. [2] To city treasury. [3] To park department. [4] Inventory.

1906. — TABLE 3. — STATISTICS OF CONSUMPTION OF WATER.

Number	Name of city or town.	1 Estimated population. Total at date.	2 Estimated population. On line of pipe.	3 Estimated population. Supplied at date.	4 Total consumption for the year. (Gallons.)	5 Quantity used through meters. (Gallons.)	6 Percentage of consumption metered.	7 Average consumption. (Gallons per day.) Total.	8 To each inhabitant.	9 To each consumer.	10 To each tap.	11 Cost of supplying water. Per million gals. Figured on total maintenance. (Item CC.)	12 Figured on total maintenance + int'st on bonds.
1	Arlington, Mass.	10 000	9 800	9 700	292 197 000	69 301 230	24	800 541	80	83	426	...	....
2	Attleboro, Mass.	14 000	13 500	....	223 793 920	....	..	640 635	43	45	...	...	....
3	Belmont, Mass.	4 550	4 350	4 250	....	57 395 800	..	272 900	62	..	...	...	....
4	Beverly, Mass.	18 000	18 000	18 000	519 152 436	....	..	1 420 168	79	79	...	$39 35	....
5	Billerica, Mass.	2 850	1 900	1 600	30 763 788	....	..	84 284	..	53	...	105 11	$222 13
6	Brockton, Mass.	57 000[1]	55 000[1]	54 400[1]	718 339 756	513 537 935	71	1 957 095	34	36	287	53 06	131 78
7	Burlington, Vt.	20 500	20 100	20 000	368 257 775	203 556 600	55	1 008 925	49	50	247	61 54	85 22
8	Cambridge, Mass.	99 934	99 934	99 934	3 386 180 600	1 252 836 750	37	9 277 207	93	93	615	20 33	64 25
9	Chelsea, Mass.	38 000	38 000	38 000	1 348 310 000	305 451 457	22	3 694 000	98	98	567	51 91	60 88
10	Cleveland, Ohio	480 237	478 000	477 000	21 552 886 258	13 050 513 080	60	59 049 003	123	124	876	20 41	28 51
11	Fall River, Mass.	107 911	....	106 370	1 634 300 539	....	..	4 477 536	41	42	...	...	....
12	Fitchburg, Mass.	33 300	....	31 000	1 062 000 000[2]	....	..	2 900 000[2]	..	93[2]	...	...	....
13	Gloucester, Mass.	26 011	26 000	20 000	454 843 889	86 036 444	20	1 246 140	48	62	314	50 58	142 04
14	Harrisburg, Pa.	68 000	67 000	70 000	3 803 869 200	2 504 711 500	66	10 421 560	149	149	751	19 56	29 03
15	Haverhill, Mass.	39 000	37 900	37 400	1 696 899 610[2]	....	..	4 651 779	119	123	732	14 22	37 94
16	Holyoke, Mass.	51 609	51 309	51 034	2 127 856 000	601 384 500	..	5 829 700	113	114	1 502	...	....
17	Lowell, Mass.	96 380	95 789	95 039	1 855 607 433	909 858 986	49	5 083 856	53	53	434	58 90	83 51
18	Lynn, Mass.	85 300	85 300	85 300	1 873 454 975	850 000 000	40	5 132 753	60	60	359	60 00	94 00
19	Madison, Wis.	25 000	....	23 766	....	191 394 096	..	....	57	..	362	...	....
20	Marlboro, Mass.	14 072	13 700	13 300	202 340 250	90 924 700	45	554 120	39	42	242	46 29	148 89
21	Met. W.W., Mass.	913 710	....	....	43 369 310 000	....	..	118 820 000	130	..	...	...	....
22	Middleboro, Mass., Fire Dist.	4 700	4 400	4 100	112 318 000	50 721 789	45	307 720	73	79	339	...	....
23	Minneapolis, Minn.	275 000	220 000	209 000	6 426 708 815	2 511 393 000	..	17 607 421	64	..	...	...	....
24	New Bedford, Mass.	83 000	77 000	76 000	2 524 786 872	807 861 000	32	6 916 880	83	91	643	16 07	43 35
25	New London, Conn.	22 000	20 800	20 000	892 903 000	....	..	2 446 300	111	122	632	11 53	36 05
26	Newton, Mass.	38 000	37 600	37 500	811 365 333	514 000 000	63	2 222 919	59	59	290	...	....
27	Oberlin, Ohio	5 000	4 200	3 200	64 000 000	35 000 000	55	176 000	35	55	191	90 20	109 70
29	Providence, R. I.	219 800	....	219 800	5 491 558 313	....	60[2]	15 045 365	68	..	600	...	....
30	Reading, Mass.	5 725	5 625	5 125	53 551 083	....	..	146 715	26	29	118	117 93	270 40
31	Reading, Pa.	93 620	93 370	93 530	4 349 047 530	1 404 947 863	32	11 915 199	127	127	576	12 67	16 38
32	Somerville, Mass.	71 000	71 000	71 000	2 248 741 000	....	..	6 301 000	89	89	...	...	....

33	Springfield, Mass. . . .	80 230	78 000	77 500	3 832 500 000[2]	778 281 426	20	10 500 000[2]	131	135	939	$14 27	$19 98
34	Taunton, Mass. . . .	30 967	28 500	28 000	698 149 375	287 297 278	41	1 912 738	62	68	386	44 02	93 00
35	Waltham, Mass. . .	27 350	27 200	26 950	705 360 048	76 121 745	11	1 929 726	71	71	533	53 95	94 96
36	Ware, Mass.	8 594	8 305	8 181	128 538 540	84 121 223	65	352 160	42	43	426	66 14	....
37	Wellesley, Mass. . .	6 315	6 070	5 030	99 481 861	61 061 440	61	272 553	43	54	268	...	....
38	Westerly, R. I. . . .	13 500	12 000	11 000	265 092 500	....	..	723 540	60	66	445	37 77	88 18
39	Whitman, Mass. . .	7 223	....	....	51 412 500	....	..	....	..	..	...	...	....
40	Winchendon, Mass. .	6 229	3 700	2 976	40 305 620	19 641 157	49	110 429	18	37	168	94 12	178 48
41	Woonsocket, R. I. .	36 957	37 457	36 957	446 420 731	326 048 066	72	1 223 070	33	33	419	37 59	....
42	Worcester, Mass. . .	138 891	136 582	136 582	3 363 756 000	2 082 903 499	61	9 217 384	66	69	373	26 95	70 09
43	Yonkers, N. Y. . . .	68 000	67 000	67 000	2 543 288 786	....	51	6 967 914	82	..	1 050	...	....

[1] Including Whitman.

[2] Estimated.

1906. — TABLE 4. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — MAIN PIPES.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
										Hydrants.		Gates.				
Number.	Name of city or town.	Kind of pipe.	Sizes of pipes. (Inches.)	Length extended during the year. (Feet.)	Length discontinued during the year. (Feet.)	Total length in use. (Miles.)	Cost of repairs. (Per mile.)	Number of leaks. (Per mile.)	Length of pipe less than 4 ins. diam. (Miles.)	Number added.	Total in use.	Number added.	Total in use.	Number smaller than 4-inch.	Number of blow-off gates.	Range of pressure on mains. (Pounds.)
1	Arlington, Mass.	C. I., Cem. L.	4–12	757	....	35 7	$4 47	..	..	...	364	3	302	...	...	50 & 90
2	Attleboro, Mass.	C. I., W. I., Cem. L.	1–24	....	....	51 2	....	..	..	11	380	...	....	...	...	85–100
3	Belmont, Mass.	C. I.	2–12	2 247	0	21 0	....	0	0 5	3	163	7	264	25	12	15–100
4	Beverly, Mass.	C. I., Cem. L., Galv.	1–24	22 197	12 256	70 1	26 99	1 5	..	24	364	21	655	...	...	72
5	Billerica, Mass.	C. I.	6–12	....	....	9 7	....	0 1	..	...	103	...	84	...	4	54–120
6	Brockton, Mass.	C. I., Cem. L.	6–30	17 415	0	100 7	2 09	43	4 5	38	877	83	1 197	72	44	47–56
7	Burlington, Vt.	Cem. L., C. I., W.I.	4–30	240	0	40	....	..	4 8	...	218	...	679	70	14	70–85
8	Cambridge, Mass.	C. I.	2–40	7 443	1 357	128 1	....	18	2	15	1 046	19	....	0	...	55–60
9	Chelsea, Mass.	C. I.	2–16	2 542	....	39 6	....	..	0 1	10	319	6	441	0	41	50–75
10	Cleveland, Ohio	C. I.	3–48	160 982	18 353	677 0	11 05	0 46	2 6	324	7 966	685	14 941	...	...	20–100
11	Fall River, Mass.	C. I.	6–24	....	....	101 6	....	..	..	23	1 153	29	1 170	...	...	80
12	Fitchburg, Mass.	C. I., W.I., Cem. L.	2–30	2 214	....	72 6	....	..	..	13	593	10	660	...	...	75 & 165
13	Gloucester, Mass.	C. I., Cem. L.	1–20	5 130	....	63 1	27 31	0 07	19 6	3	303	12	483	152	27	15–75
14	Harrisburg, Pa.	C. I.	6–30	22 701	1 348	58	....	4	..	52	775	116	1 421	...	8	30–70
15	Haverhill, Mass.	C. I., Cem. L.	2–24	7 688	....	82	....	..	..	6	346	22	877	...	...	30–120
16	Holyoke, Mass.	W. I., C. I., Ld. L.	1–30	11 073	0	88 2	12 13	..	5 9	59	878	62	899	18	40	60–100
17	Lowell, Mass.	C. I.	4–30	27 778	....	140 5	....	..	2	42	1 271	82	1 441	30	34	17–72
18	Lynn, Mass.	Cem. L., C. I.	4–36	529	0	138	136 00	0 08	..	15	987	13	1 057	...	67	40–60
19	Madison, Wis.	C. I.	4–16	10 255	....	48 4	....	..	..	8	286	20	353	...	3	53–65
20	Marlboro, Mass.	C. I.	4–16	156	0	36 6	0 80	0 11	0 9	0	347	0	390	19	65	35–142
21	Met. W. W., Mass.	C. I., Cem. L.	6–60	....	....	83 8	....	..	..	...	....	1	361	...	...	......
	Met. Water Dist. (total in district supplied)	C. I., Cem. L., Kal.	4–60	14 16[1]	....	1535 1	....	..	..	198	13 690	...	....	...	...	......
22	Middleboro, Mass.	C. I.	4–12	2 134	12	17 9	....	..	..	3	127	8	193	...	6	40–70
23	Minneapolis, Minn.	C. I., W. I., Steel.	1½–50	82 084	0	332 7	....	..	..	179	3 893	150	2 883	...	46	......
24	New Bedford, Mass.	C. I.	4–36	13 448	2 545	106 3	7 95	0 10	0 9	34	1 105	34	1 272	114	105	25–95
25	New London, Conn.	Cem. L., C. I.	4–24	5 882	0	64	4 09	0 37	18 4	7	348	18	486	...	34	35–45
26	Newton, Mass.	C. I.	4–20	4 009	530	141 4	1 30	0 03	3 3	3	976	5	843	50	400	80–86
27	Oberlin, Ohio	C. I.	4–12	120	0	10 7	0	0	0 3	0	99	0	68	2	2	27–32
28	Plymouth, Mass.	Cem. L., W. I.	2–20	2 411	0	47 3	6 67	0 53	10 6	6	236	12	529	145	38	......
29	Providence, R. I.	C. I.	6–42	68 414	5 945	362 7	....	..	0	46	2 107	164	3 891	0	41	64–73
	H. P. Fire System	C. I.	12–24	0	....	5 6	....	..	..	0	92	...	31	...	4	114

30	Reading, Mass. . .	C. I.	6–12	675	0	29 5	$1 53	0	0	0	165	2	265	0	14	63–78
31	Reading, Pa. . . .	C. I.	2–36	12 268	3 458	109 9	25 92	1 6	0 7	31	909	81	2 752	9	...	10–133
32	Somerville, Mass. .	C. I.	4–20	5 369	....	91 3	0 86	0 09	..	17	1 067	18	1 376		136	35–100
33	Springfield, Mass. .	Cem. L., W. I., C. I.	1–36	20 687	9 252	156 8	3 37	0 14	7 0	39	1 174	137	2 377	469	90	90–120 H. S 30–35 L. S.
34	Taunton, Mass. . .	C. I.	4–20	1 493	0	82 1	....	0 15	1 6	8	877	7	623	12	60	35–120
35	Waltham, Mass. . .	C. I., Cem. L.	2–24	13 987	9 900	53 7	5 14	0 3	2 0	13	415	16	758	44	63	50–70
36	Ware, Mass. . . .	C. I.	4–12	0	0	12 6	....	..	1	...	121	1	128	13	3	90–95
37	Wellesley, Mass. . .	C. I., Cem. L.	1½–12	5 018	0	33 2	0 60	0 6	0 6	5	314	5	249	4	4	35–125
38	Westerly, R. I. . .	C. I.	4–16	288	0	34 1	....	0 09	..	2	163	2	213	...	...	......
39	Whitman, Mass. . .	Cem. L., C. I.	1–16	......	....	22 0	....	..	..	...	169	...	117	...	...	......
40	Winchendon, Mass. .	C. I., W. I.	2–14	6 682	0	20 7	....	..	2 4	4	149	6	200	36	19	40–151
41	Woonsocket, R. I. .	C. I.	4–20	8 438	0	53 2	4 92	0 09	0	13	624	22	549	0	15	50–120
42	Worcester, Mass. .		2–40	....	....	197 2	....	..	..	...	2 012	...	2 868	...	...	......
43	Yonkers, N. Y. . .	C. I.	3–30	30 215	486	103 9	....	..	0 8	78	1 111	47	732	3	24	45–130

[1] Miles.

1906.—TABLE 5.—STATISTICS RELATING TO DISTRIBUTION SYSTEM.—SERVICE PIPES.

		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Number.	Name of city or town.	SERVICE PIPE.					SERVICE TAPS.		Average length of services. (Ft.)	Average cost of services for the year.	METERS.		Percentage of services metered.	Percentage of receipts from metered water. (B) + (C)	MOTORS & ELEVATORS.	
		Kind.	Sizes. (Inches.)	Extended. (Feet.)	Discontinued (Feet.)	Total in use. (Miles.)	Number added.	Total in use.			Number added.	Now in use.			Added.	Total in use.
1	Arlington, Mass. . .	C. I., Galv. I., Cem. Lined.	5/8–6	....	...	...	58	1 877	...	$17 53	233	652	34	39	...	5
2	Attleboro, Mass. .	....	..	....	...	...	...	......	...	....	105	1 875	...	..	...	2
3	Belmont, Mass. . .	Cem. Lined, Galv.	1–6	3 325	68	7 7	44	754	76	31 82	44	754	100	..	...	...
4	Beverly, Mass. . .	Galv., Lead Lined.	3/4–4	....	...	...	145	3 845	...	....	16	139	...	..	...	...
5	Billerica, Mass. . .	W. I., Cem. Lined.	1–1½	333	...	3 8	5	278	...	....	3	164	59	71	...	...
6	Brockton, Mass. . .	W. I., Ld. Lnd., Cem. Lnd., C. I.	5/8–8	17 245	688	47 7	353	6 820	46	15 30	359	6 210	91	97	1	13
									20	8 86						
7	Burlington, Vt. . .	Galv., C. I., Lead.	1/2–6	1 550	125	19 9	62	3 696	25	13 50	119	2 983	81	85	2	41
8	Cambridge, Mass. .	Galv., C.I., Tin Lnd., Lead Lnd.	3/4–8	4 835	...	117	129	15 062	37	17 51	82	2 935	19	..	...	...
9	Chelsea, Mass.. . .	Lead.	5/8–2	2 321	...	33 1	88	6 509	26	18 26	318	951	14	56	0	5
10	Cleveland, Ohio . .	Lead, Galv., C. I.	1/2–16	....	...	...	4 436	67 519	14	....	12 001	56 168	83	86	—6	131
11	Fall River, Mass. .	Lead.	1/2–2	....	...	...	101	7 845	...	....	143	7 666	...	..	...	...
12	Fitchburg, Mass. .	W. I., Cem. Lined, C. I.	3/4–8	....	...	...	50	4 795	...	....	81	3 149	...	..	2	117
13	Gloucester, Mass. .	Cem. Lined, Galv.	1–6	2 296	...	15 6	120	3 968	20 7	36 40	6	218	6	22	...	...
14	Harrisburg, Pa. . .	Lead, Galv.	1/2–6	....	...	...	420	13 879	...	....	992	7 648	73	80	...	27
15	Haverhill, Mass. .	Lead, W. I.	1/2–2	3 920	...	44 3	98	5 796	40	16 00	41	753	12	26	1	20
16	Holyoke, Mass. . .	Cem. Lnd., Rub. Lnd., Enam., Ld. Lnd., Tin Lnd., Galv.	1/2–4	1 280	17	15	81	3 881	20	15 00	10	318	...	..	2	112
17	Lowell, Mass. . . .	Lead, Ld. Lnd., Tin Lnd., W. I.	5/8–2	10 384	...	87 5	285	11 719	36	29 63	501	8 377	71	84	...	...
18	Lynn, Mass. . . .	Cem. Lined, Lead Lined.	1/2 –4	22 400	600	109	397	13 953	40	18 00	466	4 590	40	60	...	4
19	Madison, Wis. . .	Lead.	5/8–2	5 272	...	19 6	258	3 961	...	....	282	3 865	98	..	...	...
20	Marlboro, Mass. . .	Cem. Lnd., Ld. Lnd., Lead, Galv.	3/4–2	366	0	9 4	21	2 290	18	11 52	58	34 01	59	71	...	19
21	Met. Water Dist. .	....	..	....	...	...	3 264	151 058	...	....	4 257	22 233	...	..	...	...
22	Middleboro, Mass. .	Cem. Lined, Lead.	1/2–4	1 303	56	10 3	27	908	58	....	26	439	47	69	0	7
23	Minneapolis, Minn..	Lead, Galv.	5/8–1	....	...	...	...	30 070	...	....	5 742	19 276	...	..	0	8
24	New Bedford, Mass.	Lead, C. I.	1/2–10	14 713	741	71 9	287	10 764	35	18 50	371	2 803	26	60	10	167
										5 37						
25	New London, Conn.	Cem. Lined, Galv., Lead.	1/2–4	2 856	133	12 2	157	3 873	18	11 73	27	416	10	..	0	6
26	Newton, Mass. . .	Galv., Tarred I., Lead.	3/4–6	11 515	4 160	85 8	98	7 673	59	23 93	182	6 642	87	98	1	19
27	Oberlin, Ohio . . .	Galv., Lead.	3/4–4	....	0	...	34	922	14	8 50	82	672	85	92	0	0
28	Plymouth, Mass. .	Lead, Cem. Lined.	1/2–4	535	...	6 7	77	2 278	7	6 60	....	....	...	..	0	1
29	Providence, R. I. .	Lead, C. I.	1/2–10	....	...	...	652	25 094	...	....	694	21 852	87	..	4	188

30	Reading, Mass. . .	C. I., Lead, Cem. Lined.	¾–6	4 423	87	17 1	41	1 246	108	$38 55	46	1 130	91	..	0	4
31	Reading, Pa. . . .	Lead, W. I., C. I., Lead Lined.	½–8	....	...	...	785	20 685[1]	...	....	401	1 893	9	25	58	71
32	Somerville, Mass. .	Lead, Ld. Lnd., Cem. Lnd., C. I.	½–6	8 520	...	74 1	210	11 489	...	21 13	738	2 829	25	41	0	9
33	Springfield, Mass. .	Lead, Cem. Lnd., Tarred, Galv., C. I.	½–8	....	...	...	229	11 175	...	....	556	4 850	45	46	11	308
34	Taunton, Mass. . .	Cem. Lined, Tin Lined.	¾–4	3 405	...	48 2	82	4 983	...	....	70	2 293	46	68	0	19
35	Waltham, Mass. . .	W. I., C. I.	¾–10	8 402	2 170	45 0	82	3 620	62	40 65	10	320	9	22	0	10
36	Ware, Mass. . . .	W. I., Cem. Lined.	1–2	629	15	10 2	10	827	62	....	15	834	94	..	0	10
37	Wellesley, Mass. . .	C. I., Cem. Lnd., W. I., Lead, Ld. Lined.	½–8	4 060	196	20 4	31	995	92	11 12	36	1 016	100	100	0	0
38	Westerly, R. I. . .	Lead, Iron.	½–4	3 481	0	...	47	1 624	11	10 05	48	1 374	85	91	0	9
39	Whitman, Mass. .	....	..	....	...	...	70	1 248	...	....	63	700	...	..	...	...
40	Winchendon, Mass.	W. I.	1–2	2 274	0	5 7	48	657	47	9 87	35	619	97	99	0	1
41	Woonsocket, R. I. .	Lead, C. I.	⅝–6	1 687	0	8 4	141	2 917	10	....	138	2 504	86	96	0	16
42	Worcester, Mass. .	....	..	....	...	...	...	......	...	....	....	14 466	...	..	...	...
43	Yonkers, N. Y. . .	Lead, C. I.	⅝–8	....	...	...	372	6 637	...	....	453	6 660	100	..	0	7

[1] Estimated.

COMPUTATION OF THE VALUES OF WATER POWERS, AND THE DAMAGES CAUSED BY THE DIVERSION OF WATER USED FOR POWER.

BY CHARLES T. MAIN, MECHANICAL ENGINEER, BOSTON, MASS.

[Read September 12, 1907.]

DEFINITION OF VALUE.

1. The following definition of market value was given to the witnesses who were to testify on values in a recent important law-suit.

2. "'Market value' means the fair value of the property, as between one who wants to purchase and one who wants to sell any article; not what could be obtained for it under peculiar circumstances, when a greater than its fair price could be obtained; not its speculative value; not a value obtained from the necessities of another. Nor, on the other hand, is it to be limited to that price which the property would bring when forced off at auction, under the hammer. It is what it would bring at a fair public sale, when one party wanted to sell and the other to buy."

DEFINITION OF DAMAGE.

3. The definition of the damage due to the diversion of water was stated as, "The difference in market value, before and after the diversion."

METHOD OF DETERMINING VALUE.

4. The value of an undeveloped water power depends:

First. Upon its location, the amount and uniformity of flow, head, conditions affecting the cost of construction and transmission, use of exhaust steam and need of water for other purposes than power.

Second. Upon what the power is to be used for, whether for electric lighting and railway work, through most of the hours in the day with a variable load, for some use requiring a fairly steady

load for twenty-four hours a day, or for running a textile mill or similar plant with a fairly steady load for about ten hours a day.

Third. Upon the market which can be served, whether it is secure and steady or must be built up and is somewhat unreliable.

5. The value of a privilege should be determined by comparison with the cost of producing power in such quantities and with such regularity as is required for the particular purpose for which it is to be used in a fairly economical manner at any place or places equally convenient for the transaction of the business under consideration. Sometimes the location is fixed, but oftentimes there can be a choice of locations.

6. In estimating the value of an undeveloped privilege, the steps followed are as follows:

(1) Determine the flow, including the effect of storage and pondage.

(2) Determine the net head.

(3) Determine the horse-power which can be economically developed and used each month in an average year.

(4) Determine the minimum flow and power, and from this the size of supplementary steam plant required if the power is to be developed above the minimum flow.

(5) Determine the shortage of water power during such months as there is a deficiency.

(6) Estimate the probable cost of development of the water power.

(7) Estimate the probable cost of the supplementary plant, using steam, gas, oil, or anything which is best for the location under consideration.

(8) Estimate the yearly cost of running the water power and supplementary plants, including the fixed charges on both, to produce a combined power suitable for the purpose for which the power is to be used.

(9) Estimate the cost of a steam or other kind of plant, necessary to produce the power required.

(10) Estimate the yearly cost of running this plant, including fixed charges, to produce the power required.

(11) Subtract the cost of producing the power by water power and the supplementary plant from the cost of producing

it by steam power, or some other method, alone. The difference, if positive, gives the apparent yearly saving by the use of water power. The apparent saving should be modified if necessary for location or any other thing affecting the value.

(12) Capitalize this difference at a rate which seems proper, and the result is the value of the privilege.

7. There seems to be a great difference of opinion as to the proper rate of capitalization, but in the purchase of water power privileges the buyer of his own free will assumes certain risks, as damages caused by freshets, changes of business, etc., which he will not assume for nothing. He is also basing his comparisons of cost of power upon the present cost of producing power, which cost may be reduced in the future. For these reasons, the yearly saving should be capitalized at a rate not less than 10 per cent.

8. Where a whole property is taken and the owner is free to move into an equal or more favorable location, the method and rate of capitalization given above should be used.

If the privilege is developed the total value includes the value of the plant.

9. The value of a plant will be its cost, less depreciation, up to the point where the cost of water power equals that of steam or some other power. Beyond this point, when water power costs more than steam power, the value of the improvements, although new, would not be represented by the cost but would be something less than the cost. It is the sum which could be paid for it new which would bring the total cost of water power including fixed charges down to the cost of steam power, less depreciation.

METHOD OF DETERMINING DAMAGES.

10. The damage has been defined as the difference in value of the entire property before and after diversion.

11. It is usually unnecessary to go through an elaborate estimate of the value of the whole property, before and after the diversion, for the reason that many of the items of value will remain constant. The decrease in value, if there be any, is due to the fact that the running expense is increased by the diversion, and if this increased cost of running be capitalized at the proper rate

the capitalized sum will represent the amount which the property is decreased in value, or the damage.

12. In estimating the damage to an undeveloped or abandoned power, the value before and after diversion should be estimated as described under the previous heading. The difference represents the damage.

13. If a privilege is developed and used, a valuable business carried on and a plant established which cannot be easily moved, the definition of damage still holds good, but in such a case it is customary to capitalize the yearly loss at a smaller rate than 10 per cent., as this damage is done against the owner's wishes, and as he should receive a sufficient sum from which, in his business or in some other way, he can obtain a sufficient income to make good his yearly loss. The writer has, unless otherwise instructed, capitalized the yearly loss at 5 per cent.

14. A privilege which produces a variable power and has no supplementary power is not damaged any more than if it were so supplemented, and it should be treated in the same way as though it were supplemented.

15. The writer has generally used the following method of determining the damage to an established property, due to the diversion of some of the water.

(1) Determine the flow, including the effect of storage and pondage, before and after the diversion.
(2) Determine the net head.
(3) Determine the horse-power which can be economically developed and used before and after diversion.
(4) The difference between the power used before and after diversion is the power diverted which causes damage.
(5) Estimate the additional yearly cost of running caused by the taking away of this power, of coal, attendance, and supplies.
(6) If any permanent power has been taken, that is, power which can be relied upon in the lowest flow of the stream, estimate the cost of a steam plant or portion of plant necessary to make good the amount taken in the dry month.

(7) Estimate the fixed charges on this cost of additional supplementary plant.

(8) Add the extra cost of running and additional fixed charges and the sum represents the extra yearly expense.

(9) This extra expense capitalized at a proper rate represents the damage.

16. If it is necessary for the mills to maintain a steam plant of sufficient size to run the whole mill under the conditions existing before the taking, it is clearly not necessary for the defendant to furnish or maintain any further addition to the plant, and the damages consist of the increased expense of running the plant, already installed, due to the diversion.

17. If the total power required to run the mill is so large that the steam plant must be run all of the time, then there is no extra expense for attendance or supplies due to the diversion.

18. If the total power required is such that wheel plant can run the whole work for a portion of the year alone, and for the remainder must be supplemented by steam power, the time during which the engine must run may be extended by reason of the diversion, and in such case there is an addition to the expense of running for labor and supplies for such extra time, which should be added to the extra cost of coal, and the total extra expense capitalized at a proper rate will represent the damage.

WATERSHED AND RUN-OFF.

19. Too much stress cannot be placed upon the importance of determining the flow of the stream under consideration. If careful gagings have been made extending over considerable time they are the most reliable information which can be had. If no gagings have been made, an examination of the watershed should be made to ascertain its character, all existing rainfall records in the vicinity should be collected, and an estimate made of the run-off. Assistance may be had by comparison of similar rivers, the run-off of which is known.

20. The amount of data on the flow of streams which is available is increasing each year, as careful records are being kept on many rivers by persons or corporations who are interested in these matters, and by the United States Geological Survey.

21. The amount and uniformity of the run-off are two items which enter very largely into the value. The uniformity of flow depends largely upon the storage capacity and location of reservoirs on the watershed. The areas and capacities of such reservoirs should be ascertained and the net amount which can be drawn from them.

22. In estimating the average flow-off the months should be averaged in order of their dryness instead of in calendar order. If the flow is averaged by calendar months a great many irregularities in the flow are smoothed out and some of the flow is averaged which could not be held and used. By averaging all the dry months, all the second driest, and so on, some of this evening up is eliminated, but it cannot be altogether avoided. The average flow averaged by months in the order of their dryness will be less uniform and nearer the truth than when arranged by calendar months.

23. The average year is the one used in estimating the available power or power diverted, but the effect during the year when the flow is less than the average must not be lost sight of.

FLOW USED DURING WORKING HOURS.

24. The flow at any given privilege is usually given in cubic feet per second for twenty-fours hours a day and seven days a week.

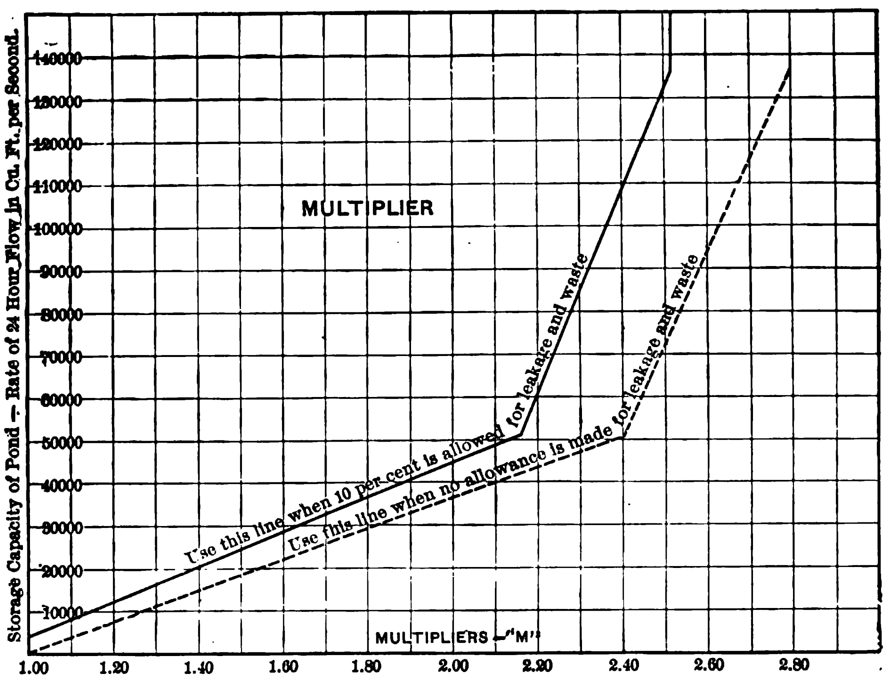
25. If the power is used twenty-four hours a day and there are no disturbing influences above to break up the uniformity of flow during the whole day, a small mill pond will answer. If, however, there are mills above using all the water in ten hours a day, a large pond would be necessary to store and use it all in twenty-four hours.

26. In a great majority of cases the water is used during the day for, say, ten hours a day and six days a week. If there is pondage enough so that it may be drawn down during the ten hours in the day enough to store the whole fourteen-hour night flow, and if no water were wasted, the ratio of the flow used in ten hours to the 24-hour rate would be 2.4; that is, 2.4 times the 24-hour rate of flow would be used during the ten working hours of the day. If the pond could be drawn down Saturday, so that the night and

Sunday flow could be stored, the ratio of 24-hour flow to that used in 10 hours a day and six days a week would be 2.8.

27. A certain amount of water is unavoidably wasted over the dam and by leakage through the various parts of the plant. This allowance of leakage and waste I usually place at 10 per cent. of the flow which could be theoretically stored and used. Using the above allowance for wastage, the maximum ratio of 24-hour flow to that which could be used in 10 hours, six days in a week, is $2.80 \times .90 = 2.52$.

28. When the pond cannot hold all of the flow during the time when the mill is not running, the ratio will be something less than 2.52, and when no portion can be stored the ratio is 1.



When "M" is less than 2.16

$$\text{"M"} = \frac{9}{10}\left(1 + \frac{S}{86000f}\right)$$

When "M" is greater than 2.16 but is less than 2.52.

$$\text{"M"} = \frac{9}{10}\left(2.4 + \frac{S - 50400f}{216000f}\right)$$

f = 24 Hour Rate of Flow in C.F.S.
S = Storage in Cu.Ft.
M = $\frac{9}{10}$ the ratio, which the amount of Water which can be used 10 hours per day, 6 days in the week bears to the total amount flowing during the week.
Main, C. T.

FIG. 1.

These ratios of amount of flow which can be used in 10 hours a day to the total flow have sometimes been called "multipliers." They are the figures by which the 24-hour rate of flow is multiplied to get the rate which can be used during the working hours.

29. The multipliers are computed for an isolated privilege by adding to the cubic feet naturally flowing in ten hours the cubic feet which can be stored each night, and to this adding one sixth the cubic feet which can be stored during the 24 hours of Sunday, and dividing this sum by the cubic feet naturally flowing in ten hours.

30. With a series of mills, some with small ponds might be enjoying the benefits of larger ones above, although they might have no rights in them. If the location were directly below the one with the larger pond, so that the lower privilege practically takes the water as it comes from the upper one, it will get the benefit of all or nearly all of the storage above. As the distance increases between the two privileges, the length of time required for the water to get to the lower one would increase and the benefit of the upper pondage would decrease. If it took one hour for the water to get down the multipliers would be 90 per cent. of those above; two hours, 80 per cent., and so on, plus any storage of water from the watershed below the upper privilege which can be stored in the lower pond.

31. Where there is a series of mills the multipliers can be computed in this way until a privilege is reached, where the multipliers due to its own storage are greater than those obtained for anything above. This power then becomes the governing one for those below it until another is reached having large enough storage to establish a new set.

32. The computation of these multipliers is tedious, and in order to facilitate the computation I have worked out the formula for them, and have prepared a diagram which reduces the labor to a comparatively small amount:

Let f = 24-hour rate of flow in cubic feet per second.

s = storage in cubic feet.

M = $\frac{9}{10}$ of the ratio which the amount of water which can be used in ten hours a day, six days a week, bears to the total amount flowing during the week:

36 000 = number of seconds in 10 hours.
50 400 = number of seconds in 14 hours, or one night.
216 000 = number of seconds in 60 hours, or one working week.
2.16 = 90 per cent. of 2.4 ratio of 10-hour flow to 24-hour flow.
2.52 = 90 per cent. of 2.8 ratio of 10-hour flow to 24-hour flow + $\frac{1}{6}$ of Sunday or 4-hour flow.

When M is less than 2.16,

$$M = \tfrac{9}{10} \left(1 + \frac{s}{36\,000\, f}\right).$$

When M is greater than 2.16 and less than 2.52,

$$M = \tfrac{9}{10} \left(2.4 + \frac{s - 50\,400\, f}{216\,000\, f}\right).$$

Fig. 1 shows the multipliers for various ratios of pondage to rate of 24-hour flow.

USE OF THE MULTIPLIERS.

33. The use of the multipliers is apparent when the problem is the determination of the amount of power which can be produced at a given place.

In estimating the damages caused by the diversion of a portion of the watershed, the power which can be produced before the diversion and the power which can be produced after diversion should also be estimated in the same manner, the difference between the two representing the amount of power diverted.

HEAD.

34. There may be several kinds of heads on the same development. There is the legal head, or the head to which the owner has a right to develop his power. This may or may not have been developed to its full extent. It may be that the expense involved would be too great to warrant further development. In some cases it might be economy to make the expenditure necessary to get the benefit of some unused portion of the head.

35. The gross head is the head actually used for producing power and getting the water to and away from the wheel.

36. The net effective head is the gross head minus the loss in head required to get the water to and away from the wheel.

This loss will vary with the length of the waterways leading to and away from the wheels, the velocity of the flowing water, and the construction of such waterways.

37. In several manufacturing cities where the water power is controlled by a company which is separate from the mill owners, there is an allowance of one foot made from the gross head before charging for the water as used on the wheels.

38. The head should be measured with the wheels running. The only portion of the head which produces power is the difference in level directly above and below the wheel when the wheel is running.

EFFICIENCY OF WHEELS.

39. Some tests of water wheels show a maximum efficiency of about 85 per cent. It is probable that over 80 per cent. is rarely realized in practice after wheels have been installed for a short time, and this is for three-quarters to full-gate opening. When the gate opening is less than about three-quarters, the efficiency begins to drop.

40. Fig. 2 shows an efficiency curve which has been published by one of the large wheel makers in their catalogue as the result of tests on one of their wheels. This is an excellent curve and represents a wheel of maximum efficiency which is not often found in practice.

41. After wheels have been run for some time the buckets and guides are not as smooth as when they are new, and the efficiency drops off. For these reasons I usually allow an average efficiency, for wheels running under ordinary conditions of age, repair, and variable gate opening, of about 75 per cent. Under exceptionally good conditions and where there are several wheels this could be increased.

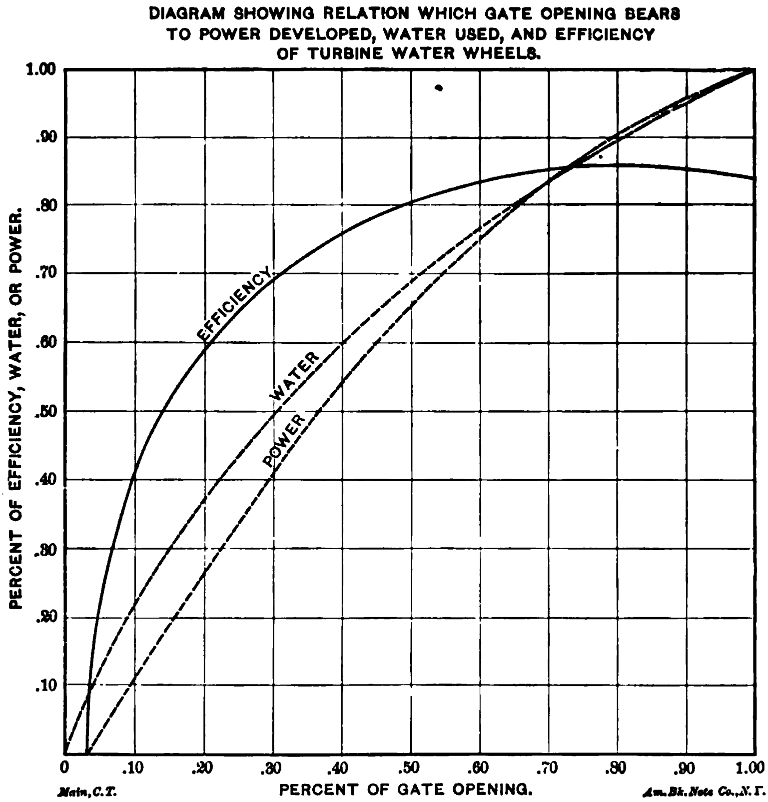


FIG. 2.

LIMIT OF LOW FLOW.

42. With vertical wheels and bevel gears, and belt drive to head lengths of shafting, the friction losses are probably from 5 to 10 per cent. of the total. With horizontal wheels the friction losses are probably from 2 to 5 per cent.

43. On Fig. 2 there is plotted in addition to the efficiency the percentage of water and of power produced for different gate openings. From this it will be seen that with a small flow the efficiency and the amount of power developed will be small, and unless the total drainage area is fairly large, or the low flow is sustained from storage, the power developed in dry months may

not be sufficient to run the wheel and overcome the frictional losses.

44. The flow required to produce 5 per cent. of the power is about 15 per cent. of the total water required to run the wheel full, and for 10 per cent. of power, 20 per cent. of water is required. With one wheel only there must, therefore, be a flow of say 10 to 20 per cent. of the total used by the wheel to produce any useful power. With several wheels properly arranged this could be reduced somewhat. At such times of low flow the water must either be stored and used for a short time in the day or it will produce no useful work.

EFFECT OF BACK WATER.

45. In a great many places there are periods during the year when the flow in the stream is so large that the water backs up below the wheel to a greater extent than the level of the water above the wheel can be raised, thus reducing the effective head and power. Sometimes the effect is so great as to prevent the use of the wheels.

EFFECT OF LOW FLOW AND BACK WATER.

46. The effect of low flow is to require an auxiliary power plant to make up the deficiency of water power, if it is necessary to run constantly, and if the flow drops so low as to produce no effective power, the auxiliary power plant must be of a capacity sufficient to run all of the work.

47. The effect of back water is to reduce the power produced by the water and to make it necessary to maintain a water power plant which has a surplus capacity in times of ordinary flow, or to maintain an auxiliary power plant and to run the same to make good the diminution of power if it is necessary to run full all the time. If the back water lasts for a long time and is so serious as to prevent any production of power from the wheels, the auxiliary plant must then be large enough to run the whole work.

LENGTH OF TIME DURING WHICH DIVERSION CAUSES DAMAGE.

48. In order to ascertain the difference in running expense due to diversion, it is necessary to know the average amount of power diverted and for how many months the diversion occurs.

This latter can usually be ascertained by knowing the capacity of the wheels in use, for in the majority of cases the wheel development will be an economical one.

49. It is sometimes the case, however, that larger wheels are installed than economy would warrant, by overestimating the flow, or some other cause. Wheels are sometimes installed to be used in times of back water, remaining idle at other times. Where the variation of the use of power during the day is large, as for electric light and railway purposes, wheels may be installed for the peak load where pondage will allow this method of running. If the length of time when the diversion causes damage is measured by the capacity of the existing wheels, it may appear to be for the entire twelve months of an average year. This cannot be true, for it would not pay to put in wheels to use all of the water in every month in the year. The diversion should be estimated for as many months as it would be economy to develop the power to use all the water under average conditions.

50. If the chance size of a wheel should be taken as measuring the length of time over which the damage continues, in a series of adjacent mills, some which had put in a portion of the wheel plant which could be used with economy would receive small damage, while a mill with a much larger wheel than would ordinarily be used would receive large damages thereby, when in point of fact the damage would be the same, other things being equal, and with a series of mills the damages would not be proportioned properly unless the wheels were installed in each on the same basis of economical development.

ECONOMICAL DEVELOPMENT OF WATER POWER.

51. In a large number of water power developments which I have examined, a very large percentage have been developed with wheel capacity sufficient to use all of the water from six to seven months in an average year, and during the remaining months water would go to waste. The economical development has been stated by some engineers to be nine months. No general statement is applicable to all conditions. It is a question of economics which requires solving for each particular case.

52. The factors which enter into the problem are on one side

the cost of the water power development and the fixed charges on the same, plus the cost of water if anything is paid for it, and on the other side the saving which can be effected by the use of such a plant.

53. The cost of the dam will be a constant for any size of wheel development, other things being equal. The head gates, canal, racks, feeders, wheels, wheel-pits, and tailraces must be increased in size and cost for the purpose of using a larger amount of water than the flow in the average month or sixth month of an average year, and the fixed charges for such increase in cost, plus the cost of water, represent the annual cost of the corresponding increase in water power.

54. The saving due to such increase in water power is represented by the saving in coal only on supplementary steam plant, necessarily run with such a varying water power, plus the cost of attendance and supplies on steam plant if it can be shut down entirely during the months of maximum power on the wheels. As the water power is increased in size to use water for a greater number of months, the cost of such increase for each additional month makes a saving for a less number of months, and there comes a time when the saving on steam power is less than the fixed charges on the additional cost of water power plant. Where these two items balance depends upon the following conditions:

(1) Cost of running the water power plant for each increment of power.
(2) Saving effected by the decreased use of steam power.

55. The variation in the cost of the water power plant per horse-power is very large. The principal causes for this are the variation in head and distance from the source of supply of the water to the point of discharge. The cost of construction will also vary with local conditions.

56. The saving effected would also vary largely, depending principally upon the number of hours run during the day, the cost of coal, and whether by increasing the size of water power plant the auxiliary power plant could be stopped during the months in which the water power was producing full load.

57. An example will suffice to make this clear. Supposing

the cost for each additional horse-power of water power plant required to use all the water for a longer period was $60 a horse-power. The fixed charges on this, including interest, will be not less than 8 per cent., or $4.80 per year. The cost of coal and attendance on a steam plant of say 500 horse-power, when running ten hours a day, with coal at $4 per ton, is about $13 per year per horse-power, or $1.08 per month. $4.80 ÷ $1.08 = 4.44 months. In other words, it would not pay to develop such a power to use all the water for more than about seven and one-half months.

58. If the engine or boilers cannot be shut down at all, a less saving could be made and the power could be economically developed for a less period than seven months.

59. The various conditions and lengths of time required to have the saving equal the fixed charges are shown in Fig. 3. This diagram is figured on coal at $4 per ton, and with a running time of ten hours a day, six days a week. Similar diagrams could be made for any other prices of coal and time of running.

60. To use the diagram, supposing the water power plant cost $50 per horse-power, and the size of steam plant is 200 horse-power. On the ordinates find $50 cost of water power plant. Run along horizontally until this line intersects the vertical line of 200 horse-power of steam plant, and these two lines will be found to intersect about on the curve marked three months.

If the water plant cost $70 and the steam plant were 350 horse-power, the time is five months during which water should waste.

TABLE SHOWING FLOW AND POWER.

61. The table on page 232 shows a convenient form for tabulating the flow and power. The first half is useful in estimating the value of a privilege, and the whole table for estimating damages when a portion of the flow is diverted.

62. The only thing needing explanation is the figure .0851 which appears in the headings of columns 6 and 12. This is the horse-power produced by one cubic foot of water per second on one foot head with an efficiency of 75 per cent. With 80 per cent. efficiency the figure is about .091.

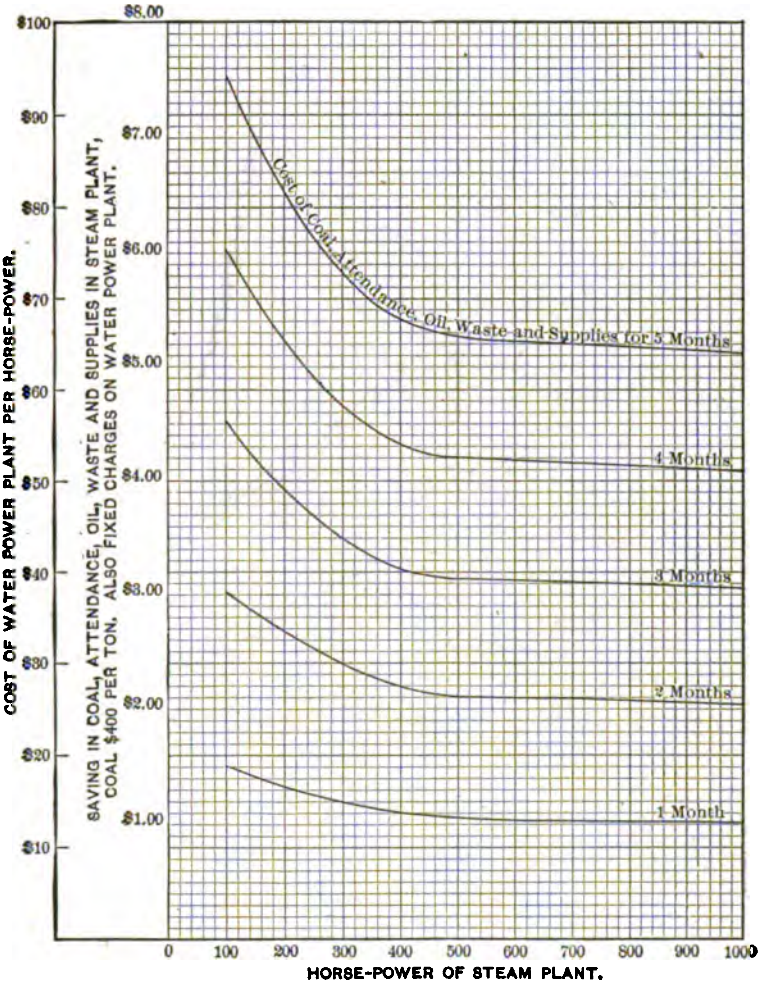


DIAGRAM SHOWING NUMBER OF MONTHS WHEN WATER SHOULD BE ALLOWED TO WASTE WITH DIFFERENT SIZES OF STEAM PLANTS AND DIFFERENT COSTS OF WATER POWER.

Main, C.E. Am.Bk.Note Co.,N.Y.

FIG. 3.

APPROXIMATE COST OF WATER POWER DEVELOPMENT.

63. In connection with the preceding diagram is printed a table, page 231, showing approximately the cost per horse-power of water power plants, not including dam, canal, and buildings, for different heads, distances from feeder head to end of tailrace, and horse-power of development.

It is not expected that this table will cover all cases, but it will give approximate figures for ordinary conditions, and is useful in making rough preliminary estimates.

TABLE OF ESTIMATED COSTS PER HORSE-POWER OF WATER POWER PLANTS

HAVING HORIZONTAL TURBINES, STEEL PENSTOCKS, AND WALLED TAILRACES —DAM AND BUILDINGS NOT INCLUDED.

	"L".	10-ft. fall.	15-ft. fall.	20-ft. fall.	30-ft. fall.	40-ft. fall.
1,000 H.-P.	100 feet	$65.14	$40.92	$29.37	$19.40	$14.59
	200 "	71.91	45.48	32.84	21.70	16.38
	300 "	78.66	50.05	36.30	24.01	18.17
	400 "	85.43	54.62	39.77	26.32	19.95
	500 "	92.20	59.18	43.23	28.63	21.74
	600 "	98.96	63.75	46.69	30.94	23.53
900 H.-P.	100 "	65.35	41.00	29.56	19.56	14.79
	200 "	72.08	45.58	33.04	21.85	16.60
	300 "	78.80	50.16	36.53	24.14	18.41
	400 "	85.50	54.74	40.01	26.41	20.22
	500 "	92.24	59.32	43.49	28.70	22.03
	600 "	98.96	63.91	46.97	30.99	23.84
800 H.-P.	100 "	65.48	41.10	29.65	19.68	14.99
	200 "	72.22	45.68	33.12	21.98	16.78
	300 "	78.95	50.26	36.68	24.28	18.57
	400 "	85.70	54.84	40.04	26.56	20.35
	500 "	92.43	59.41	43.52	28.87	22.14
	600 "	99.15	64.00	46.98	31.17	23.93
700 H.-P.	100 "	65.72	41.19	29.87	19.90	15.12
	200 "	72.48	45.75	33.35	22.19	16.93
	300 "	79.23	50.30	36.82	24.49	18.73
	400 "	86.00	54.86	40.29	26.77	20.54
	500 "	92.74	59.42	43.77	29.07	22.34
	600 "	99.50	63.97	47.25	31.37	24.16
600 H.-P.	100 "	65.86	41.56	30.00	20.03	15.37
	200 "	72.64	46.14	33.49	22.34	17.20
	300 "	79.42	50.72	36.97	24.64	19.04
	400 "	86.20	55.30	40.45	26.95	20.87
	500 "	92.98	59.88	43.94	29.27	22.70
	600 "	99.76	64.47	47.42	31.57	24.54
500 H.-P.	100 "	66.00	41.70	30.24	20.24	15.52
	200 "	72.82	46.32	33.78	22.56	17.31
	300 "	79.64	50.94	37.28	24.86	19.10
	400 "	86.46	55.56	40.80	27.16	20.88
	500 "	93.28	60.16	44.34	29.48	22.66
	600 "	100.10	64.80	47.84	31.80	24.44
400 H.-P.	100 "	66.28	42.03	30.55	20.79	16.00
	200 "	73.16	46.65	34.05	23.10	17.82
	300 "	80.03	51.26	37.53	25.40	19.64
	400 "	86.90	55.88	41.03	27.73	21.45
	500 "	93.78	60.50	44.53	30.03	23.27
	600 "	100.65	65.13	48.03	32.35	25.08
300 H.-P.	100 "	66.87	42.67	31.09	21.49	16.50
	200 "	73.70	47.30	34.57	23.83	18.33
	300 "	80.54	51.94	38.07	26.18	20.16
	400 "	87.33	56.54	41.54	28.53	22.00
	500 "	94.17	61.18	45.04	30.88	23.83
	600 "	101.00	65.78	48.51	33.22	25.67
200 H.-P.	100 "	68.50	44.22	32.45	22.61	17.60
	200 "	75.35	48.84	35.97	24.97	19.47
	300 "	82.25	53.45	40.04	27.33	21.34
	400 "	89.10	58.10	43.56	29.70	23.21
	500 "	96.00	62.70	47.08	32.06	25.08
	600 "	102.85	67.35	50.60	34.43	26.95
100 H.-P.	100 "	71.39	46.64	34.76	24.75	19.80
	200 "	78.43	51.37	38.39	27.17	22.00
	300 "	85.47	56.10	42.02	29.59	24.20
	400 "	92.51	60.83	45.65	32.01	26.40
	500 "	99.55	65.56	49.28	34.43	28.60
	600 "	106.60	70.28	52.91	36.85	30.80

NOTE: "L"—Distance from Feeder Head to end of Tailrace. Cost of Canal, if any, not included.

TABLE .... NAME ....

	Flow and Power before Diversion.							Flow and Power after Diversion.						Power Diverted.
Col. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Months in the order of their dryness.	Natural flow in cu. ft. per sec. on one square mile.	Total flow cu. ft. per sec. = Col. 2 × square miles.	Multiplier or ratio of flow which can be used in 10 hours to 24-hour rate.	Total flow which can be used in 10 hours a day = Col. 3 × Col. 4.	H.-P. which can be used in 10 hours a day on one foot fall = Col. 5 × .0851.	Total H.-P. which can be used in 10 hours a day = Col. 6 × ft. head.	H.-P. which present wheels can use or which would ordinarily be developed.	Total flow cu. ft. per sec. = Col. 2 × square miles.	Multiplier or ratio of flow which can be used in 10 hours to 24-hour rate.	Total flow which can be used in 10 hours a day = Col. 9 × Col. 10.	H.-P. which can be used in 10 hours on one foot fall = Col. 11 × .0851.	Total H.-P. which can be used 10 hours a day = Col. 12 × ft. head.	H.-P. which present wheels can use or which would ordinarily be developed.	H.-P. diverted which causes damage = Col. 8 − Col. 14.
Dryest.....														
2d "														
3d "														
4th "														
5th "														
6th "														
7th "														
8th "														
9th "														
10th "														
11th "														
Wettest........														
Totals and Averages...														

Average H.-P. diverted .... for .... months in an average year ....

EXTRA LENGTH OF TIME WHICH STEAM PLANT MUST RUN ON ACCOUNT OF DIVERSION.

64. If the power of the stream before and after diversion, is worked out it will probably be found that the auxiliary power plant must be run for a longer time after the diversion.

65. This would be shown in full months in the tables showing the power before and after diversion, but it would not show fractions of a month.

66. The method of ascertaining the extra length of time is shown in Fig. 4. The ordinates show horse-power which the whole stream can produce and the abscissæ the number of working days. By plotting the horse-power which can be developed before and after diversion, and drawing diagonal lines from month to month, the extra number of days when the auxiliary plant must run is shown where the diagonal lines cross the horizontal line of wheel development.

DIAGRAM SHOWING EXTRA LENGTH OF TIME WHICH ENGINE WOULD HAVE TO RUN IF INSTALLED AFTER DIVERSION.

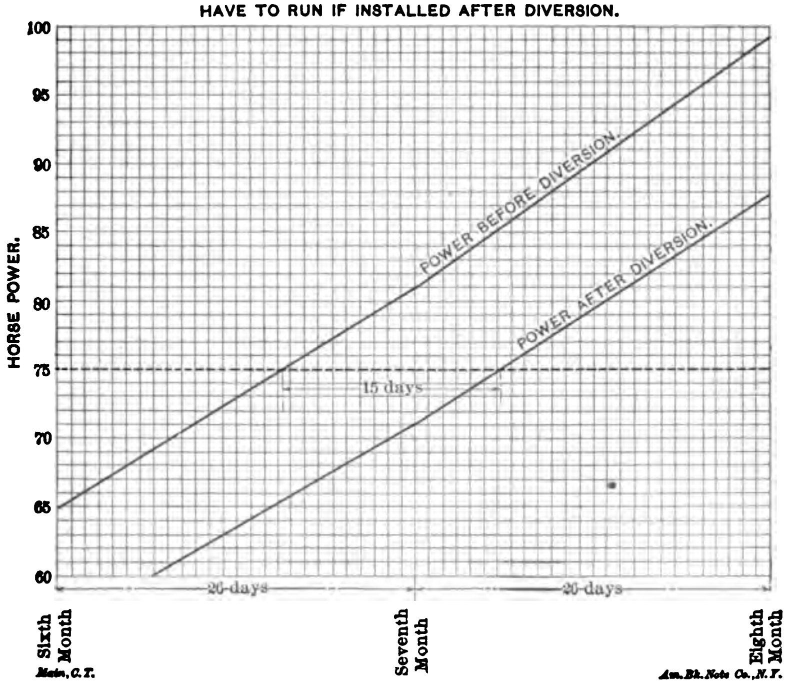


FIG. 4.

STEAM OR OTHER POWER PLANT TO BE USED IN MAKING GOOD THE POWER DIVERTED.

67. In order to determine the damage, it is necessary to estimate the cost of replacing the power taken away, not necessarily by the auxiliary plant already existing at the mill, for such a plant may be an extremely uneconomical one and the mill which had the poorest plant would get the most damages, but by a *fairly economical plant of the size and character such as the business under consideration would naturally use.* Unless this method is pursued with a series of mills, the one which had put itself into the best shape would receive a smaller amount of damage than its neighbor where things were in bad shape.

68. It is improbable that a concern would go on putting in each time it renews its plant an uneconomical plant, and it is highly probable that the low-grade engine will be improved in efficiency.

As the damages are figured forever, it will add very little to the damages for the comparatively short time which the uneconomical plant will be obliged to run.

PRIVILEGES WITH NO AUXILIARY PLANT.

69. The basis on which the damages should be estimated in these cases where there is no auxiliary power plant is the same as for any other. The mere chance that an owner can manage in some way to run his business in accordance with the fluctuating flow of the stream does not entitle him to any greater damage than his neighbor who is fitted up to run continuously. A small amount of power diverted will not make the conditions enough worse in most cases to require the addition of a supplementary plant for that reason alone. An allowance, however, should be made in estimating the damages in such cases for such portion of a steam plant as would ordinarily be installed to produce a uniform power as is equal to the power diverted in the dry month, and the running expenses should be estimated on a plant of full size and not on a very small plant.

70. The proper method of ascertaining the damages to a plant of this sort is to find the difference in value before and after

diversion, and this is obtained by finding the cost of producing a uniform power before and after diversion.

ALLOWANCE FOR PERMANENT POWER DIVERTED.

71. If any power is diverted which can be depended upon all the time, an allowance should be made for this. If the diversion is comparatively small the fixed charges should be allowed on the cost of a portion of the large plant equivalent to the amount of power diverted. Thus, supposing 5 horse-power is diverted in the dry month, and the cost of the steam plant is \$60 per horse-power: 5×\$60 = \$300. \$300 @ 12% = \$36. This capitalized at 5% = \$720.

If this allowance is made the owner may increase the capacity of his plant by 5 horse-power when he renews it, and will have been recompensed for this expense.

If the interest charges are not included in the fixed charges, the cost of plant, \$300, should be added to the capitalized sum.

If the diversion is a comparatively large amount, it may be necessary to remodel and increase the existing steam plant, or to put in a new one. Allowance should be made in the same way for this.

COST OF STEAM POWER.

72. The cost of steam power usually has an important bearing upon the settlement of damages. The accompanying Figs. 5, 6, and 7 have been prepared, which show the yearly cost of producing steam power under various conditions and costs of coal when running ten hours a day and six days a week with a fairly steady load. They are intended to show the expense of running under everyday conditions on such a plant as a prudent man would install and run with ordinary skill.

The cost of 24-hour power for 365 days a year is about 2.2 times the cost for 10-hour power for 308 days.

The cost of 24-hour variable load cannot be stated without knowing all the conditions.

COAL CONSUMPTION USED IN ESTIMATING DAMAGES.

73. The coal consumption used in estimating damages when the power diverted must be made good under a varying load contingent

upon the fluctuation of the water power should be somewhat larger than the coal consumption for a fairly steady load. I have usually added about 20 per cent. to the coal consumption required for a steady load. The fluctuation of the water power will usually

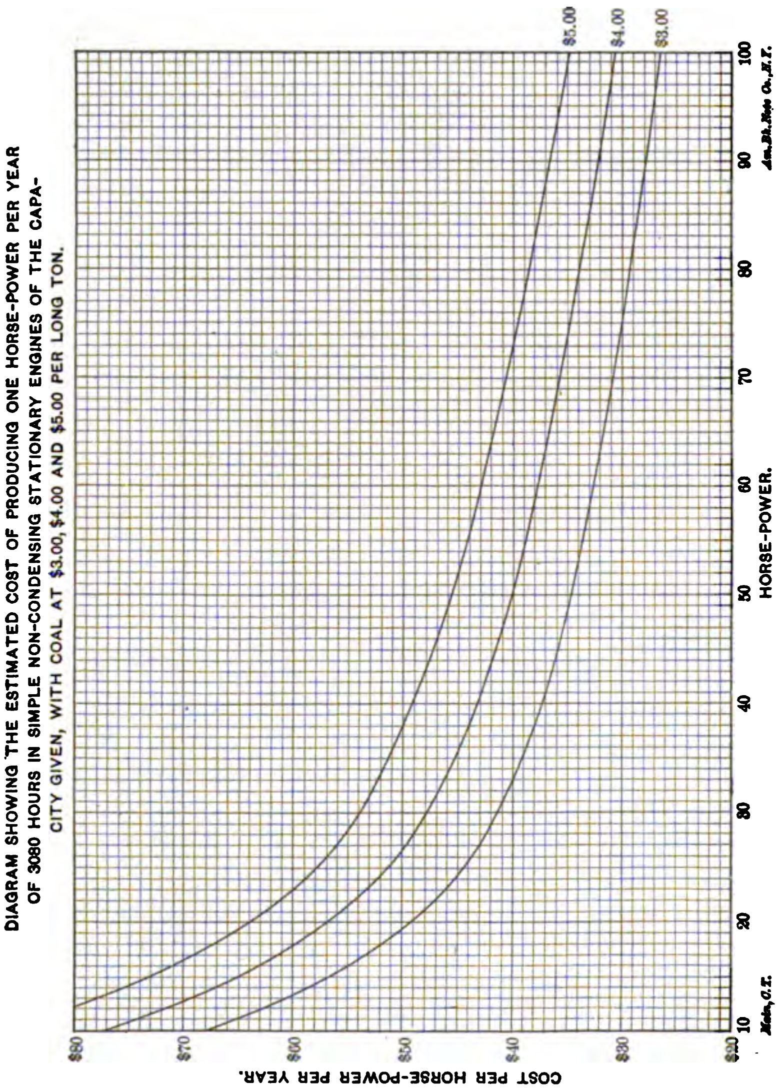


FIG. 5.

not be great for a single day, but the variation covers longer periods, as weeks or months.

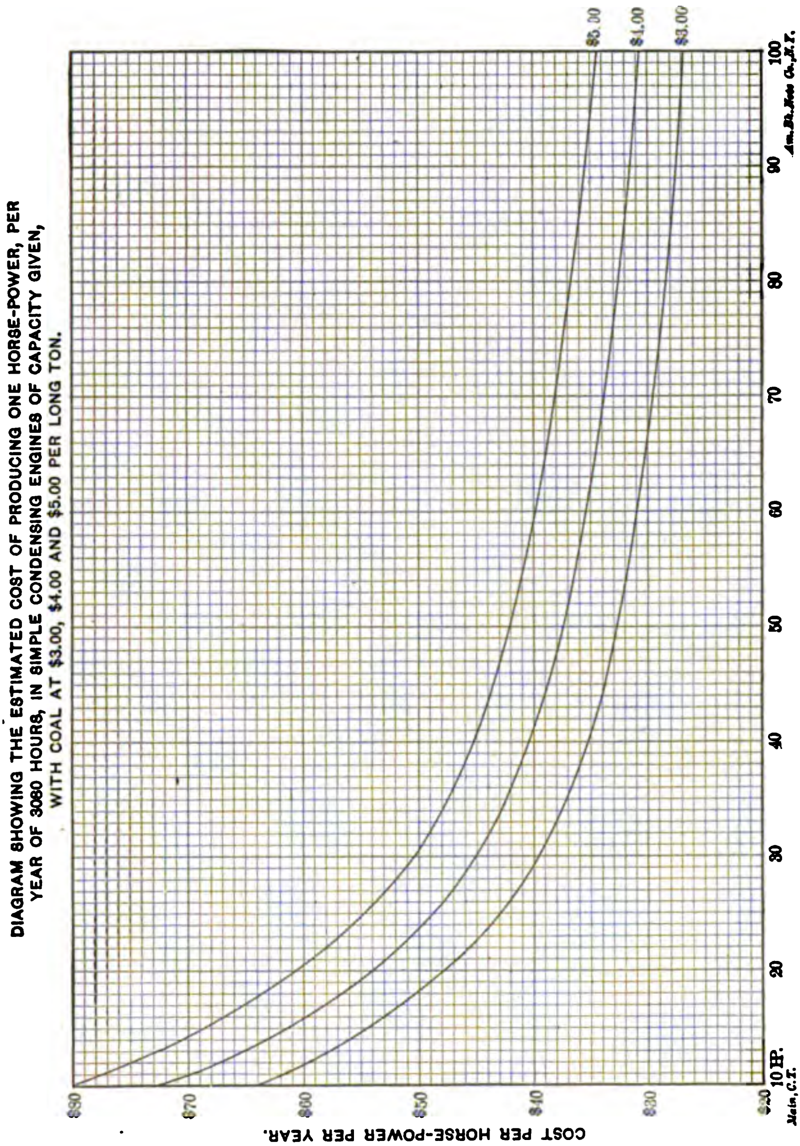


FIG. 6.

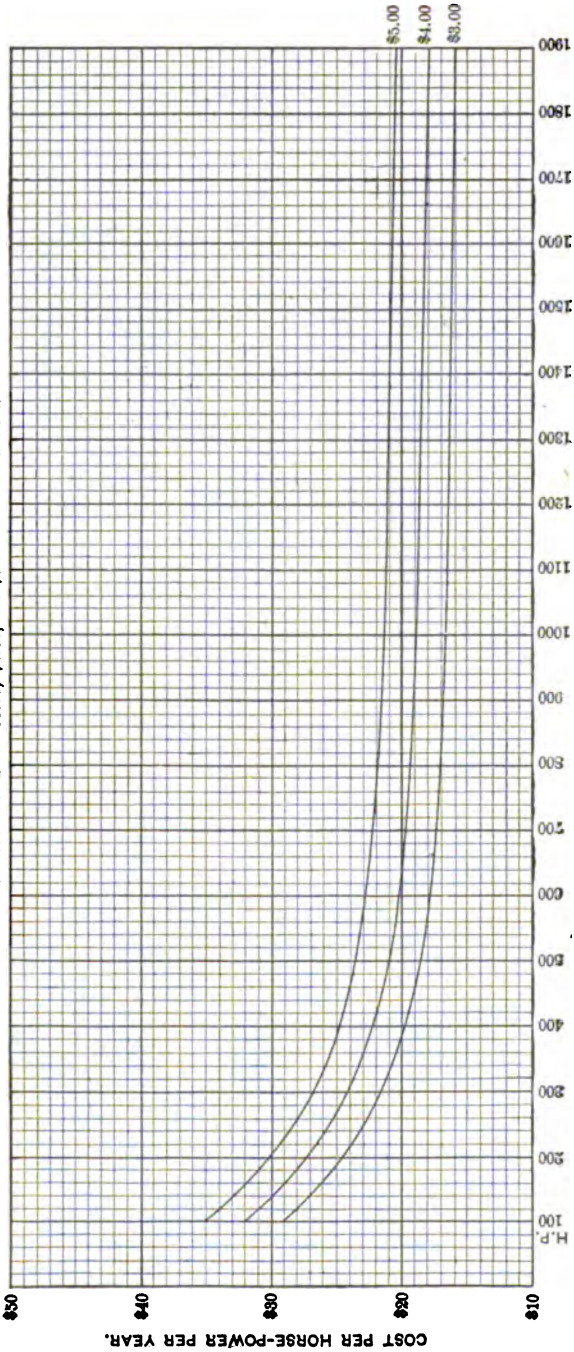


DIAGRAM SHOWING THE ESTIMATED COST OF PRODUCING ONE HORSE-POWER PER YEAR OF 3080 HOURS, IN COMPOUND CONDENSING ENGINES OF THE CAPACITY GIVEN. WITH COAL AT $3.00, $4.00, OR $5.00 PER LONG TON.

FIG. 7.

EFFECT OF USE OF STEAM FOR OTHER PURPOSES.

74. In many textile and other mills low-pressure steam and hot water can be used in the manufacturing processes, and for warming the buildings. The amount varies largely, in some cases being more than the equivalent amount of steam exhausted from an engine large enough to run the work, or to the amount of water required for condensing for an engine of the same size. Rarely in a textile mill would the amount fall below 20 per cent. of the total heat rejected by the engine. This has the effect of reducing the value of water power for such mills, and has the effect of reducing the damages as figured on straight power conditions.

75. It is never attempted, however, to estimate this effect in suits for damages. It should be considered in estimating values, and it has its effect upon the selling value of water powers, making them of less value for industries having use for low-pressure steam and warm water.

76. All of the varying conditions of different industries have an effect of producing a sort of average selling value for water powers, but each case requires examination and estimates of its own.

EFFECT OF ELECTRICAL TRANSMISSION.

77. The statement is frequently made that water powers have increased in value since it became possible to transmit power electrically.

78. To be correct the statement should be modified. Since the introduction of electrical transmission many water powers which were before unavailable and valueless have been developed and become of value, and many others will be in the future, but water powers which have been developed and the power used adjacent thereto have, as a rule, not increased in value.

DETERMINATION OF VALUE OF REMOTE POWERS.

79. All of the preceding described methods are applicable to the determination of the value of a remote water power which may be capable of development with electrical transmission to some market, but there must be added one or two steps in the process.

80. To the cost of the development must be added the cost of the electrical apparatus and pole line to a point where the power is to be used, and this is a large item of expense in long-distance transmission. Usually, also, there must be added to the cost of the physical part of the plant a considerable amount for right of way for pole line, legal expenses, and cost of financing the scheme.

81. To the running expenses must be added the fixed charges for the electrical apparatus and pole line, and the cost of running and maintaining the same.

82. A correction must also be made for the loss of power in transmission.

83. A comparison of the cost of producing and transmitting power can be made with the prices which can be obtained for this power to determine if the development has any value, and whether the development is warranted or not. The price which can be obtained for the power depends largely upon the cost of producing power by steam, or in some other way, at the point of delivery.

POWER USED FOR ELECTRIC LIGHTING AND RAILWAYS.

84. In the majority of developments for electrical transmission the power is used to a large extent for electric lighting and railways; sometimes, in addition, for manufacturing purposes, and occasionally for manufacturing only.

85. When used for lighting and railways the power is usually exceedingly variable, resulting in a low power factor. The conditions are so variable that it would be useless to try to show in this paper the probable cost of power produced by steam under such varying conditions. Each case must be worked out to meet the special conditions of the problem under consideration.

DAMAGES CAUSED BY THE DIVERSION OF WATER POWER.

BY CLEMENS HERSCHEL, CONSULTING ENGINEER, NEW YORK CITY.

[Presented September 12, 1907.]

A full discussion of this subject necessarily treats of legal matters about as much as it does of hydraulic or other engineering. It must, indeed, be founded on a consideration of the fundamental rule of law, frequently quoted, that the measure of damage done a piece of real estate by the diversion from it of a certain quantity of water hitherto flowing through it is the difference between two market values of that piece of real estate, the one estimated or judged as of date before the taking of the water right; the other appraised as of date after that taking.

Two sums of money are to be attained or determined in the minds of the masters or other tribunal charged with the duty of awarding the damage done or suffered in such cases, and their difference is the sum of money to be awarded to the claimant. Nothing simpler, one is tempted to say at the beginning of such hearings; only a simple sum in subtraction to be performed. And yet no class of cases has probably given rise to greater wrangling or presented at times a more lamentable spectacle of the incompetency of man to undertake the perfect administration of that one of the highest of divine attributes — the administration of justice.

There is, we will assume, no dispute as to the work to be done so far described, no dispute as to the rule of law to be applied as it has been above stated. Let us, therefore, briefly comment on the words and language of the statement made and recall some elementary principles and definitions not always present in the minds of laymen to the law, but to which experts in engineering must give due heed if they would aid in the administration of justice and be experts in fact as well as in name.

Our comments may follow the order of words as above written in stating the rule of law to be followed, and we thus come upon the words "real estate."

(1) These cases deal with damage to a piece of real estate.

They do not ordinarily deal, certainly not as far as the engineering expert is concerned, with damage done to the business carried on upon this real estate, nor with that done any particular individual. It is the real estate that is damaged, and it is this injury which is to be measured by a difference in its market values at two different dates.

(2) *Diversion of Water.* It may be hardly necessary to state that, inasmuch as all flowing water, as a rule, is held appurtenant to real estate, when some or all of this flowing water is prevented from reaching such real estate, an act of what is called diversion has taken place, and this causes the damage in such cases complained of.

(3) *Market Value.* A sum of money that can only be arrived at by the opinion of a properly constituted tribunal from evidence put before it, or generally by a concensus of opinion of men having knowledge of market values, that is, of the values of such property as it is bought and sold in a market that is neither stimulated nor constrained; that is, in a natural, open market, as between a party ready to sell and another willing to buy.

At first it might seem to an engineer as though the simplest way to compensate for the diversion of water from a piece of real estate would be by turning an equal quantity of water into the stream from some new source of supply, such as a storage reservoir to be constructed for that express purpose, and which would supply, when needed, water which had been stored out of freshet river flow; which not only was not needed, but might even be detrimental to others, the claimant included, if not thus withdrawn and stored in times of high water. Especially does it seem strange to an American engineer that this method of paying for water diverted by the gift to the parties injured of a compensating reservoir, as it is called, is not followed in the United States, when he knows that for a hundred years or more this has been and yet is the accepted method in Great Britain.

Many years ago, not being able to cause any one, learned or unlearned in the law, to give a satisfactory answer to my inquiries on this point, I had to study it out for myself, and was obliged for this purpose to import several acts of parliament authorizing the construction of such compensating reservoirs. Acts of this sort,

being of mere local concern, are not likely to be found elsewhere than in Great Britain, even in the best of law libraries, but a reading of them is extremely instructive in more ways than one; among others as illustrating the gulf that separates the rights, duties, immunities, and privileges of the citizen of Great Britain from those of a citizen of these United States. From such an act of parliament it quickly appears that, whereas a citizen of the United States lives under a government in which the legislature may enact laws, but cannot act as a judicial body (except in cases of impeachment), nor perform executive work, and the judicial and executive branches of the government are similarly each strictly confined to its own branch of government work, "to the end," as says the constitution of the good old Commonwealth of Massachusetts, "that this may be a government of laws and not of men"; the parliament of Great Britain, on the other hand, has powers "so transcendent and absolute that they cannot be confined, either for causes or persons, within any bounds."

And we find, in fact, that parliament, through its committees, habitually sits as judge and jury and awards damages, when it considers private legislation, and puts its awards into the clauses of such acts; nothing of which work any of our legislatures nor Congress can possibly do. It is under these powers of parliament that compensation reservoirs have been and continue to be built in Great Britain, with minute directions how they are to be maintained and operated, and, if desired, parliament could itself operate them.

Then, again, the state cannot authorize any one to "take property without just compensation"; and it is a settled principle of law in this country that a "just compensation" must consist of money paid over, and cannot consist of anything else. Every person has, moreover, the right of an appeal to a jury of his peers and countrymen at some stage of the proceedings, to say what amount would be a just compensation, and cannot be deprived of this, his right of appeal. So that though such compensating reservoirs have repeatedly been proposed, and in one instance — some sixty years ago, at the time of the construction of the first (the Cochituate) water works to supply Boston — were actually built, they could not be used to pay damages by substituting water

delivered for water diverted. Whence it appears that, stating cause and effect in juxtaposition, we may say that when Montesquieu, in 1748, in his "Esprit des Lois" (The Spirit of Law) first stated the necessity in a free state of separating the duties of the legislature, the executive, and the judiciary from each other (a principle which, as is well known, was adopted by all the American constitution builders of the eighteenth century), he decreed that American engineers could not build compensation reservoirs to pay for water diverted.

At first glance this may seem a result that is deeply to be regretted, so perfect, physically, is the form of compensation for water diverted made by water supplied. But there is a good deal to be said on the other side, and, as usual, it is weak human nature that is at fault. The difficulty comes in the course of time, on account of failure to compel the responsible parties properly to keep in repair and operate the compensating reservoirs year after year without pecuniary interest in having it done, and on account of the manifold changes of value that take place in the life and interests of the people. So that, for one, I have come to the conclusion that Montesquieu, in 1748, builded wiser than he knew in the matter of compensation reservoirs, and that for a practical, live people the payment of damages in money, the full and complete settlement of damages as they arise, and by the generations as they pass across the stage of life, is the better way.

It has been suggested that a city, by obligating itself to maintain and operate certain compensation reservoirs, could show that it had not diminished certain water rights, hence that no damage had been done, and there would be no damages to pay. But a jury would have to decree to that effect; a riparian owner has the right to have the water flow through his estate "without alteration," whether he were injured or not, and even were he benefited for the time being. In the United States he must be paid damages in money if he wants them, and he generally does.

We have seen that a substitution of water for water diverted is unlawful and impossible in payment of damages in the cases we are considering. Equally so should be, but with uninformed tribunals is not always, the substitution of steam or other caloric or transmitted power for water power diverted. Such substitu-

tion offends against the rule of law quoted, which is based wholly on market values, and justly so, as will plentifully appear. Suppose, for example, that the water power taken were situated within the site of a storage reservoir, to be buried eventually under 50 feet or more of water. If now a computation were made for that case of any form of substitution of steam power, the whole of the water power being taken, it would result in a computed award made by the engineering expert that would have no proper relation to and might be twenty or thirty fold the market value of the real estate taken, either before or after the diversion of the water under consideration. That is to say, it would have no application whatever to the case in hand; it would be wholly irrelevant and out of place for the expert to give it, and going further, he should know or be taught that such testimony is not aiding the court in its work. And if such testimony is wholly wrong or mistaken in one such case, because it does not instruct as to market values, the like testimony in other cases, if of no instruction in market values, is equally improper and may be grossly misleading.

Here, indeed, is the true test of such scientific or engineering testimony: Will it instruct experts in market values, or has it no readily discernible connection with market values? If the former, it is good; if the latter, it can only mislead.

Other cases repeatedly come before the masters in such cases in which the estimated values of substituted steam power have no direct bearing or give no instruction upon market values before and after the taking of the water diverted.

Such are the damages to an undeveloped mill site; to a mill driven wholly by water power in a place where steam power is a practical absurdity, and many more. There is every degree of bearing upon market values of testimony relating to steam power; from cases of no bearing at all of the cost of a substitution of steam power, such as have been cited, to those of the cost of a little extra coal burned on account of a minute percentage of diversion, which, in the mind of the buyer and seller in the market, may form an approximate indication of effect produced; from which, again, by a concensus of such opinions, the effect of the diversion on the market value may be arrived at.

If the rule of law first above quoted is good, it must be applied to all cases of damages to real estate by a diversion of water. It cannot be ignored where palpably it will not apply,—such as in the case of the reservoir site above referred to, or of the place where steam power is an absurdity, or of the undeveloped mill privilege,—and then adopted and values of a substituted steam power used in other cases.

If it is a rule of law, as we are told it is, it must hold in all cases; not have one law for the rich in opportunity and another for the poor.

Strictly speaking, all such cases require two distinct sets of experts, the one to measure the damage done in horse-power diverted and similar damage done; the other, consisting of assessors, real-estate agents, parties who have bought and sold mill property in the vicinage, etc., to appraise the value of the property before the diversion, and to appraise what that property was worth in the market since the acts complained of had taken place; which latter appraisal they may properly base on the results of the computations made by the first-named set of engineering experts.

Engineers with experience in cases of this class know that claims of ten fold and twenty fold the awards finally made, and of a *twentieth part of a water right* being computed worth more than the *whole piece of real estate* originally was worth, are no rarity, and are based on the computed cost of a substitution of steam power, capitalized, for the water power diverted. Engineers are responsible for the appearance of such claims in such cases, which would not appear and could not appear under a consideration by them of market values and of the rule of law noted. So absurd have these computed damages been in the past, being based simply on the capitalized cost of a number of horse-power equal to that of the water diverted, that able engineers, Mr. Main as a leader among them, have mitigated such computed damages by assuming a certain steam power present, and computing merely the cost of the additional fuel or power needed, after the diversion has taken place, to maintain the former total output of power per annum. This undoubtedly is more instructive as to the effect of the water diversion on market values, for the market is composed of both

buyers and sellers, and the average man in the market is, after all, Carlyle to the contrary notwithstanding, no fool out of the "1 500-000 000 inhabitants of the earth, mostly fools." But the principle must not be lost sight of, that we are establishing in the trial of such cases *two market values*, and the business of the engineering experts is to aid the appraisers of such values in the case in hand to reach a conclusion on market values; and it is not for the engineers to compute what the damages in dollars and cents in such cases may have been if based on any form whatever of substitution of steam power for water power; any more than it is to estimate the cost of bringing in additional or substituted water power or transmitted electric power, or any other power, and calling that the measure of damages. If the results of computations offered do not square with sensible market values, this will constitute proof positive that the methods which were followed by the computer were in error, and hence that they can not with propriety be used by him or any one else.

Closely allied with this subject is the broader one of the "Best Use to be Made of Experts in the Conduct of Judicial Inquiries." It would lead too far, however, to attempt here a discussion of that subject. It was treated at length by the present writer in 1886 in a paper which was printed by "Direction of the Committee of the Bar Association of the City of Boston on the Amendment of the Law."

If this class of cases were more frequently tried in any one community, the awards to be made would, no doubt, speedily reach a normal measure. That is to say: — within limits, a market value for such damages would become established. Nothing might at first seem more fanciful than to expect an established schedule of damages adopted for the loss of a limb, or an eye, or other member. And yet the Pension Bureau, which deals with such cases by the hundred or thousand, has adopted such a schedule; so much for a right leg gone below the knee, another price for the whole leg, one price for the left eye and another for the right. Similarly it may be said that these mill damages in the last forty years in the New England states, when not notoriously excessive (they do not often err by being notoriously too small), have ranged from $50 to $100 or $125 per million gallons per day diverted, used

on one foot of fall. From which the value of a stated quantity of water diverted, used on any stated fall, may be judged between limits, or approximated, but taking into consideration all the attendant circumstances of the case in hand.

WATER RIGHTS.

BY RICHARD A. HALE, PRINCIPAL ASSISTANT ENGINEER, ESSEX COMPANY, LAWRENCE, MASS.

[*Read September 12, 1907.*]

The subject assigned to me to present this morning covers a very wide range of details, any one of which would easily occupy the allotted time. As the previous speaker has discussed the diversion subjects so thoroughly, I will confine my paper largely to the general subject on which the diversion matters depend.

In all diversion cases the main point to be first ascertained is the water rights of the company or individual, and what water and power can be depended upon before any diversion takes place. Water rights in general at any mill privilege comprise the use of the water for power and various manufacturing purposes, and when controlled by one individual or company no serious complications are liable to arise. When, however, the power is owned by several parties, questions may arise producing serious entanglements in the subdivision of the water, especially during the dry periods of flow. The early deeds relating to water rights were often vague and indefinite in relation to the subdivisions. A few examples will illustrate my meaning. The Essex Company, controlling the water power of the Merrimac River at Lawrence, leases the water in " mill powers." A mill power is the right to draw from the nearest canal or water course so much water as shall give a power equal to 30 cubic feet of water per second when the head and fall is 25 feet, to be drawn sixteen hours per day. As the height of water varies with change of seasons, the quantity of water is varied in proportion to the height, one foot being deducted from the height of the fall and also from that with which it is compared before computing the proportion between them; thus

for any fall the quantity of water to make a mill power is

$$\frac{750 - 30}{\text{Fall} - 1}.$$

The one foot is allowed for the loss of head in reaching and leaving the wheels. This definition of a mill power giving a constant power is explicit, and during the sixty-one years in which it has been in use, has admitted of but one interpretation and has never been questioned. The leases at Lowell, Holyoke, Turners Falls, and Bellows Falls are written on the same general lines, although in one locality the quantity of water is not varied in proportion to the fall as the fall changes. At Cohoes, N. Y., the "mill privilege," as it was called, was the right to draw from the canals of the company 100 square inches of water when the head and fall is 20 feet, that is, 3 feet head and 17 feet fall, to be drawn through a gap of cast iron or other metal having an aperture 2 inches deep and 50 inches in length, with the edge of the aperture not less than 1 inch in thickness; and in the same ratio for a head and fall greater or less than the above named.

Mr. J. B. Francis, the eminent hydraulic engineer, by agreement of the various mill owners, made experiments in 1859 with a head of 3 feet acting on the center of this form of orifice, and ascertained the quantity to be 5.9 cubic feet per second. Shortly after this, new proposals fixing 6 cubic feet per second on 20 feet fall were adopted for all future sales of water power.

Not all rights are so clearly defined or settled as those above mentioned, and a few examples are given of more obscure rights. One of the most prominent cases is the "Smith's Pond" water rights at Wolfboro, N. H., involving one dam at the outlet of the pond and two other dams just below on Smith River. Tradition says that disputes began in 1778 and have been waged at intervals ever since. However that may be, the quarrel began again in 1896, and at date of this writing matters are still before the court. The main questions were the rights in using the quantities of water from Smith's Pond at various times and the amounts that could be drawn throughout the year. With several different interested owners, and not very clearly defined water rights, the case has dragged along encumbered with legal questions, with no

immediate prospect of settlement. The writer and the late Mr. Freeman C. Coffin were associated with the case in the early days, but withdrew two years ago, feeling that little progress was being made towards settlement. Mr. Arthur T. Safford, consulting engineer at Lowell, Mr. H. D. Mears, and Mr. Lewis D. Thorpe have been called in at various times. One principal question which could have been settled if left to the engineers was the yield of the pond with storage, to see what could be drawn in various periods of the year. Definite observations were not taken in such a manner as to arrive at satisfactory results. The rights of the parties varied. One owner had the right to run when the pond was full, and others had rights to drive certain machinery. Estimates and measurements of the various water wheels were made with the quantity of water that was used and subdivisions made of the water. The hydraulic problems involved the amount of water that could be conveyed by certain sized penstocks, estimates of water necessary to drive wood-working machinery and grist mills, and the probable discharge of an old-fashioned tub wheel.

A more recent case, which involves various water rights in Hinsdale, N. H., may be of interest as being applicable in many places. A company was formed in 1839 in Hinsdale for the purpose of building a dam, canals, etc., and developing power for manufacturing purposes. Eight persons were interested in the scheme and owned the power in certain proportions measured by square inches. Various questions arising in regard to the quantities of water, in 1859 bulkheads of plank were placed at the entrances to their flumes, and orifices having the areas of their legal number of square inches were made in the bulkheads, at the proper distance below the surface of the water in the canal, by a legal decree of the court. The number of inches and head were very definitely stated, but thickness of the orifice plate was not mentioned. One party was entitled to the surplus in the river after all others had been supplied with their legal rights. In 1867 it was agreed by the manufacturers that the canal should be enlarged to carry an increased quantity of water, and to improve the general conditions of water power, and $1 500 was expended in this manner. It was also agreed that whatever increase was obtained should be divided *pro rata*, according to the number of

square inches owned by each party. At about this date the upper portions of bulkheads were removed and water was drawn over the top with no reference to orifices, and the amount of water drawn was limited by the capacity of the water wheels. In the year 1885 suit was brought, by parties owning the right to surplus, to compel the restoration of the upper portion of bulkheads, but nothing definite was accomplished. In 1905, owing to changes made by parties owning the surplus, a suit was brought against them by the remaining owners on the grounds of excessive use of water. The rights of all parties were to be determined. The writer had made some investigations for the parties entitled to the surplus, and the late Freeman C. Coffin was engaged by the other parties to the suit. As there were many hydraulic problems involved and engineering facts, that it seemed unnecessary to work up in duplicate, which would have to be ascertained in a suit in court, the writer suggested that the engineers should consult together and make a joint report. This was agreed upon by all parties, and the court appointed Freeman C. Coffin and the writer as engineering members, and Hon. J. H. Frink, counselor-at-law of Portsmouth, as the legal member of the commission. The commission were to hold hearings and make a report to the court as to the amount and the methods of drawing the water to which each was entitled. Several hearings were held, and testimony was given in regard to enlargement of canals and past use of water, and a report was made giving the amounts of water to which each was entitled under varying conditions of flow. The main problem was to determine the surplus previous to 1867, and what additional surplus was gained by enlarging the canal at that time, which was to be divided among the owners. All additional surplus belonged to the eighth party. The questions of the yield of the stream and capacity of the canal were considered and the fact that the parties had used the water for a long period (about twenty years), without remonstrance, was given weight. A system of measuring weirs was recommended and adopted by which each party should draw the amount to which it was entitled. As the parties were not entitled to quantities of water on an equal basis, but certain ones had priority over others, it was necessary to adapt the lengths and heights of the weirs to fit these conditions as far as possible.

Various adjustments were made after the weirs were placed in position. Another difficulty arose from the fact that the surface slope in the canal varied with varying quantities of water, necessitating heights of weir crests which were correct for one quantity and not strictly accurate for another. By experimenting with varying lengths and heights of weir, the quantity which each was entitled to draw was decided with a fair degree of approximation. For very small flows, tables of heights were given, showing when parties should cease drawing in the order of their decreed rights. Two of the rights have been combined, making one party less in the final division. In the later years no special efforts were made to maintain the rights of each owner, which, if maintained in a systematic manner, would have avoided the extensive investigation and adjustment. An objection to the use of measuring weirs occurs in the fact that they reduce the available head on the wheel. One other plan was proposed, that of attaching gages to the wheels and from the fall and openings regulating the quantities. This would require much more detail, and the owners preferred to lose the head during the low period of flow and have an automatic measurement rather than to require so much detail by the other method. During the period when water was abundant there was practically no head lost. Before the final report was made, both Mr. Coffin and Mr. Frink were removed by death and Mr. Lewis D. Thorpe, a partner of Mr. Coffin, who was familiar with the details, was appointed to fill the vacancy caused by Mr. Coffin's death. It is hoped by all parties that the matter is finally settled after long and tedious investigations.

Another case in the same locality occurred where a woolen mill and paper mill were on the same dam and the power was divided in the proportion of two thirds and one third of the flow of the river. As the paper mill used water for twenty-four hours, and the woolen mill for ten hours, various complications arose, and the matter was finally adjusted by measuring weirs dividing the flow of the stream proportionally. The storage capacity was very small above the dam and the vexed question of the difference in use of ten and twenty-four hours did not receive a weighty consideration.

The above examples have been stated somewhat in detail to

illustrate the importance of water rights being clearly defined when various parties are mutually interested, and also to illustrate the complications that may arise from neglecting such details.

As previously stated, in water diversion cases one of the main questions is to determine the amount of water which can be depended upon for power and the general flow of the stream. Most manufacturers have a general idea through their master mechanics of the amount of power at their mill privileges, but it is often stated in such a general way that it is not of value to an engineer as an accurate record. A system of keeping records of the flow of the stream at a small water power is not a complicated matter, and very valuable data may be collected without great expense. The general outline of the method is to use the water wheels as water meters and the overfall of the dam as a weir to measure the amount not drawn through the wheels. The Hydrographic Department of the United States Geological Survey has used this method, and various papers relating to the flow of streams and methods are familiar to all engineers engaged in hydraulic work. Messrs. R. E. Horton and H. K. Barrows of the Geological Survey have made special studies and reports on these general lines. A brief illustration is presented of the method as used at the Marland Mills, Andover, where measurements on the flow of the Shawsheen River were conducted for three years. The plant was a 14 set woolen mill with a breast wheel and a turbine situated on one side of the river and a second turbine on the opposite side of river. A separate flume led the water to each wheel. Gages were established in various locations, and the crest of the dam was fitted with a planed plank set at a uniform height (by a leveling instrument) to measure the water which wasted over the dam. All gages were set to a uniform datum plane and distributed as follows: The gages consisted of white pine boards 6 inches by 1 inch, painted white and marked in feet and tenths and half tenths and secured to posts attached to wall. One was set in the pond above the dam, which was used for obtaining the depth on crest; others were set in each forebay or flume above the wheel, to use in obtaining the fall on the wheels; another series were set in the raceway, to show the height of water after leaving the wheels. The difference between the two readings showed the fall on the

wheels. The total amount flowing in the river was then the sum of the following:

1. Amount wasting over dam.
2. Amount drawn by wheels.
3. Amount used for manufacturing purposes, such as dye house, boilers, etc.

1. The amount wasting over dam was deduced from the depths shown by the pond gage. Owing to the shape of the crest, the Lawrence dam formula applied to good advantage. An ideal apparatus would have been a self-recording gage to show a continuous record, but at this period, twenty-five years ago, such gages were not as available as at the present time. Readings were taken by the carpenter connected with the mill at intervals of two hours during the day, and the watchmen took a height in the evening, and one in the early morning, which were assumed to give a fair average of flows during the night. The readings were plotted with heights and times of observations on cross-section paper, and a line joining the observations showed the range above the dam. From the average line the amounts wasting during working hours and outside of working hours were determined. In this particular instance the working hours were from 6.30 A.M. to 12 M., and 1 P.M. to 6.30 P.M., stopping at noon Saturday. As additional to the convenience of this division, it indicated at a glance what water was available, if any, for an extra wheel at any portion of the year and the value of the pond for storage purposes. The ratio of the waste to the total flow and other interesting comparisons were deduced.

2. The amount of water drawn by turbines. In using the wheels as water meters, it is necessary to ascertain their discharge at various openings of the speed gates. The Holyoke tests form an excellent basis for these data. Changes in form of buckets and guides of wheels and outlet areas, variation in lengths and size of draft tubes often change the discharge, and it is desirable to measure the water as actually used by each wheel. If the wheel is running in connection with a steam engine, as is frequently the case, measurements may be made at various gate openings, thus determining the discharge, from which tables can be made. To determine the opening of the gate, a convenient method is an iron

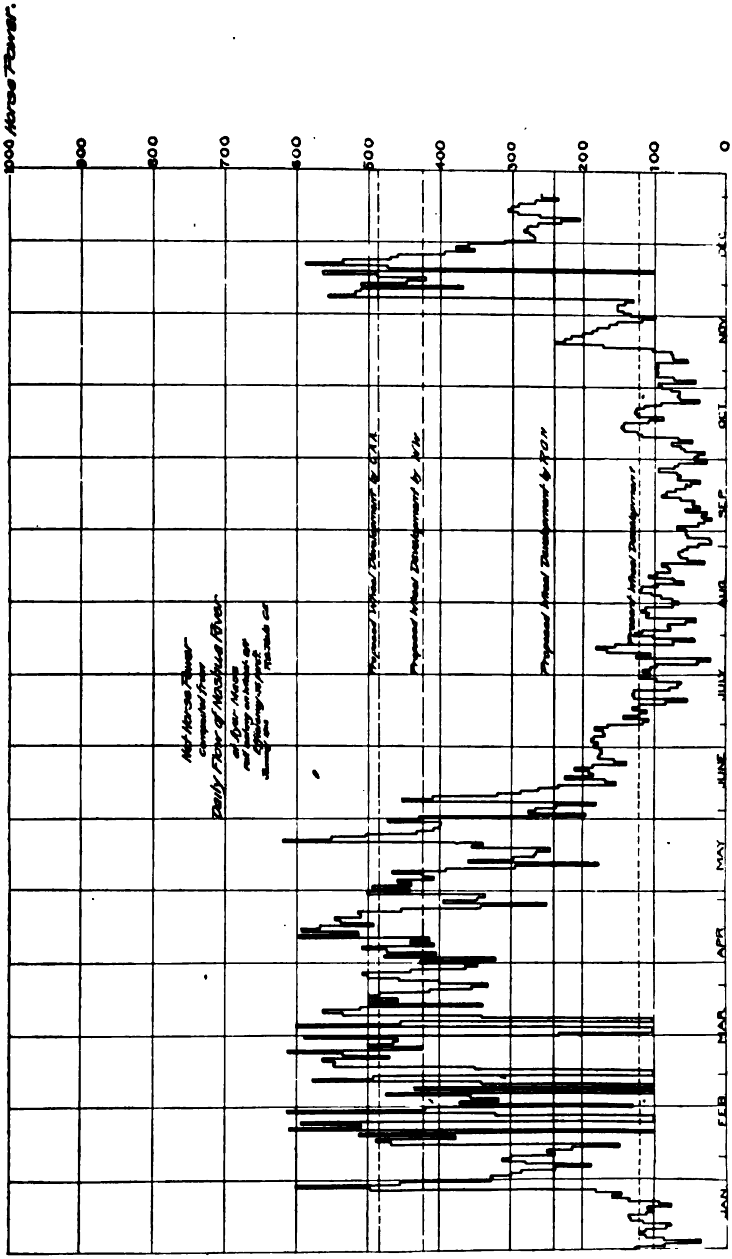
or brass rod attached to the rack iron of the speed gate and of sufficient length to project through the wheel case where a scale divided in feet and tenths shows the amount of opening. Dial gages and pointers may be used if more convenient.

Measurements of water may be made by submerged floats or current meters in rectangular flumes or by weirs in the raceways. Diagrams of discharge show graphically the amounts discharged at various gate openings and falls acting on the wheels. At the Marland Mills the wheels were measured by submerged floats and weirs, and tables calculated for other falls than those observed. The heights of the speed gates were observed at intervals during forenoon and afternoon, and an average height used in determining the flow. The number of hours was noted that the wheels were run, as during the dry period it was necessary to shut off wheels a portion of the time. Wheels run at noon hour were recorded, and water used in the dye house and for scouring was measured at a separate outlet. Combining the quantities for the periods for which they were drawn gave the yield for twenty-four hours. It was necessary in measuring the quantities outside of working hours to ascertain the leakage from wheels and various pipes in dye house, etc., accurately, as this often formed a large percentage of the flow during a dry period. A similar system can be readily adapted to any mill privilege and records kept with but slight expense. The results in connection with rainfall on the area are of great value in the knowledge of the yield of the stream and its value for power. In these results the valuable data thus obtained show how the flow of the stream is distributed throughout the working hours and outside of working hours, and the amount available for actual use. The percentage of waste which cannot be utilized on account of lack of storage, sudden rains, and variable use by other parties on the upper portion of the stream is always a question of discussion in water division cases. The amount of 10 to 20 per cent. is often used in diversion cases and is a reasonable amount. The storage capacity is a large factor in this matter, and in Lawrence, on the Merrimac River, with considerable storage there has recently been a period of a month when no water was running over the dam. On a smaller stream the range of percentages of 10 to 20 per cent. would be reasonable.

It is often possible to place a gage in a stream unaffected by dams below, which should give a correct index of the quantity of water passing. The quantity of water must be measured with various readings of the gage and a diagram constructed showing the actual quantity flowing at various heights. For the flow of twenty-four hours a continuous record of the gage must be taken and the average height for that period taken. If the water power is used chiefly during the ten working hours, a reading of gage taken during period of steady flow may be used after ascertaining its relation to the average for twenty-four hours.

The records of a large water power, as the Merrimac River at Lawrence, are kept in the same general methods, but necessitate more details. Flashboards on the dam are kept in good condition and levels are taken on the crest of the boards at intervals so that from the depth flowing over the boards the quantity of water may be computed. Outside of working hours the head gate openings furnish a means of measurement in the canals and various leakages through wheels and waste gates, etc., are measured and combined in the twenty-four-hour flow. The results are of value to show what extra water may be depended upon if surplus is desired. A gage is located in the river near the lower end of canal and readings of this gage indicate the quantity of water flowing as ascertained by previous computation. During the period of ice floating in the river when the flashboards are broken and pins bent over, it is necessary to use this gage in ascertaining the quantities. These periods are quite infrequent and in general the more exact methods are used.

In the customary method of ascertaining the yield of a stream, the average of the driest months is taken for a series of years, then the next driest, and so on. This is preferable to the calendar months where a wet January of one year would be averaged with a dry January of another year and present misleading figures. After a manufacturer has collected his data showing the average yield per month, the power can be computed and the average power for the year ascertained. Another table can be arranged showing the conditions after a portion of the water is diverted, and the difference shows the average loss for year. In computing the power month by month it will be borne in mind that wheels are


1000 Horse Power.
900
800
700
600
500
400
300
200
100
0
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
DEC

1900

FIG. 1.

generally installed to use the capacity of the stream up to the eighth month. There are periods of large flows and reduced heads when a wheel may be used supplementary to the regular power, but whether it is a profitable investment to run four months and to remain idle during the remaining eight months must be considered. In the use of turbines the efficiency is reduced on very low flows; the speed gates are open a small amount and the efficiency is poor. After diversion occurs, the smaller quantity that is left will be used with less efficiency on the turbines and this loss is often very appreciable. If great difference exists, it may necessitate new wheels of other capacities to be adapted to the new conditions.

In some diversion cases where daily flows have been observed, a diagram showing the available horse-power for each day before and after diversion and the capacity of the water wheels illustrates the actual condition without involving a series of averages which smooth out the irregularities. An example is shown in Fig. 1, the

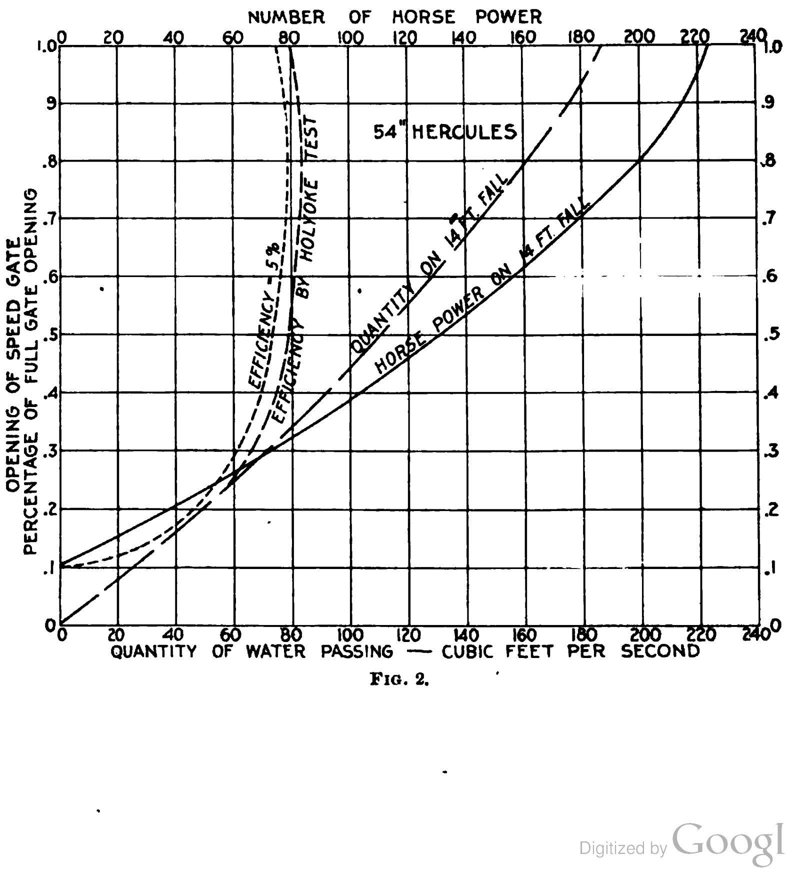


FIG. 2.

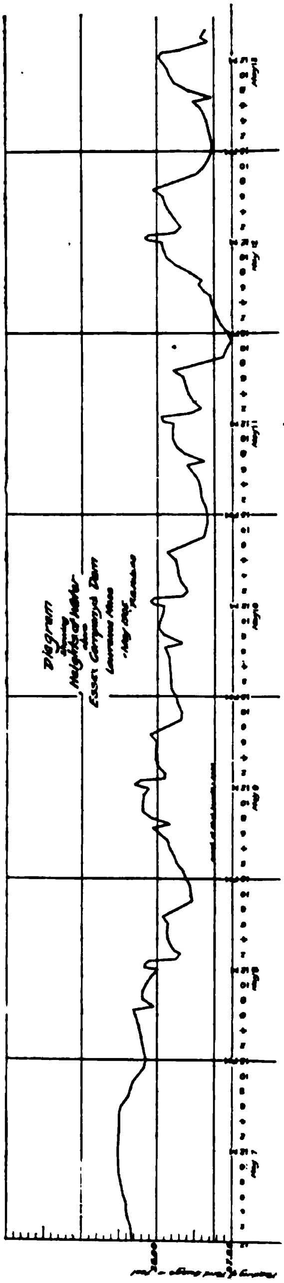


FIG. 3.

diagram of daily horse-power at Nashoba Company on Nashua River, which shows the variations in horse-power which exist in the variable flow of the stream. The necessity of installing a steam plant to supplement the small amount of power obtained during the dry months is shown by the large area between the various wheel developments and the actual power. During sudden storms and rises of the river, water is lost by wasting as indicated by sudden rising in the spring and fall. The lines shown for wheel development were used by various engineers in the diversion case.

Diagrams for obtaining graphically the horse-power from the wheels, percentage of efficiency, etc., with the quantities of water discharged at various gate openings, are useful in presenting the cases, and an example is shown in Fig. 2. In Fig. 3, the diagram of height of pond above dam at Lawrence is plotted from hourly observations and the range of heights of water shown by the irregular black line. The horizontal line shows the crest of flashboards. An average height is taken for intervals of one or more hours, depending on the variation of heights. The quantity of water is computed from the J. B. Francis weir formula, or, if the flashboards are gone, the Lawrence dam formula is used.

The financial damage from the diversion of the water varies with the condition of each case and no fixed general rule can apply. With combined steam and water-power plants and varying conditions in the use of steam and engines, a special investigation must apply in each case. The general expenses connected with the engines and maintenance are well known and can be ascertained from well-kept records. The general expenses of water-power maintenance vary in each case. Repairs on dam and canals, care in winter for anchor ice, snow storms, etc., often increase the expenses materially.

I have preferred to deal with this branch of the subject without taking up the subject of financial damage due to diversion which would extend the paper to an unreasonable length and has already been ably presented. It should be stated, however, that the manufacturer should receive a fair compensation for the water diverted and the expenses of running by steam and water considered and a sufficient sum be paid to cover the annual loss which exists.

DISCUSSION.

MR. H. K. BARROWS.* Mr. President, I have little to say, except to express my general interest in the subject. Mr. Main's paper interested me in the matter of wheel capacity; that is, the amount of horse-power or the number of wheels that should be installed in a new plant. Some data on that subject would be of interest, showing how installations vary for different uses. For instance, in the case of pulp and paper manufacture, installations are often made for two or three times the amount of water expected during eight or nine months of the year, the idea being to use this excess installation in grinding the pulp when there is plenty of water, and then later on using the pulp in the process of paper manufacture. Perhaps Mr. Main could give us a table showing about what he considers to be the proper wheel capacity for the different types of installations.

The matter of keeping a record of flow is, of course, one that has interested me greatly, and frequently it can be done, as Mr. Hale has said, with little expense to the mill owners, furnishing informa-

* Civil Engineer, Boston, Mass.

tion of great value. It is too often the case that when this information is very much needed, it is not available, in questions of water rights or in improving a plant, as these records must be obtained over a series of at least a few years to be of conclusive value.

In the adjustment of the flow of water and the consideration of water rights there is a further division of the subject that has not been mentioned, *viz.*, that of securing and operating additional storage and apportioning the cost of this among different mill owners upon the river in question. The common situation, on such of our New England streams as furnish good natural facilities for storing water, has been that some one of the power users on the river has acquired control of this storage and operates it; usually, however, to the benefit of others on the river, and with no cost to these others. The time is approaching, however, when storage of water for power use during the low-water season will be attempted on a larger scale; and to make this profitable, the expenses of construction and maintenance must be borne by all who are benefited.

The necessity of careful and systematic regulation of flow from storage reservoirs has in many cases not been realized. Thus in the State of Maine the three large power streams, the Kennebec, Penobscot, and Androscoggin, are naturally equipped with lake systems, well up in the head-waters, which furnish admirable facilities for storing water. The development of this storage has, however, been slow, and, until within a few years, almost entirely for purposes of log driving. The Kennebec River is especially well equipped with lakes and ponds, comprising Moosehead Lake with 115 square miles of water surface, and the numerous other large lakes of the tributary Moose, Roach, and Dead rivers. The regulation of Moosehead Lake, at present the only one of these lakes used to store water for power purposes, is in the hands of the Kennebec Water Power Company, which company is made up of the principal owners and operators along the main river.

Log driving and lumbering interests in this river are represented by the Kennebec Log Driving Association. As these two companies are made up largely of the same parties, the present control of the lake storage is entirely harmonious. Log driving, however,

requires a large amount of water, and at times when it should be stored for power uses. No systematic regulation of flow from Moosehead Lake is maintained and much water is wasted, especially during the log-driving season. The speaker has shown in the case of Kennebec River * at Waterville, where some of the large power interests are situated, that during the period of 1893–1906 a low water flow, never less than about 2 500 second feet (depending upon what assumptions are made for water used in log driving), could have been secured, by a proper control of storage facilities at *existing* dams. As a matter of fact, a mean monthly flow as low as 921 second feet was reached at Waterville during February, 1904, showing how little attempt has been made to regulate flow on a river where large power interests are already situated.

The development and control of water power is now being considered by several of the states. New York, for example, under the "Fuller Bill," has recently passed an act "authorizing and directing the state water supply commission to devise plans for the progressive development of the water powers of the state, for the public use, under state ownership and control"; Pennsylvania and New Jersey have also enacted laws relating to state control of water resources. The water-power project of to-day is coming to be more and more one involving storage, and some interesting questions of water rights and assessments will be brought about by state control, in the apportioning of betterments occasioned by storage, among existing water powers.

It seems reasonable to predict that our rivers in the future will be "operated" by means of storage reservoirs, as far as can be done with economy, — conserving the spring and fall floods to provide water for power users during the periods of drought, and incidentally preventing disastrous floods. Whether state or national control will be needed to properly carry this out and develop our water resources as they should be, is a question of great interest and importance.

MR. LEONARD METCALF.† I have listened to these papers with much interest, and one or two questions have occurred to me;

* See Water Supply and Irrigation Paper No. 198, U. S. Geological Survey.
† Consulting Engineer, Boston, Mass.

one particularly along the line raised by Mr. Barrows, — a question which I thought of asking Mr. Main and Mr. Hale, — whether they chance to know of any cases in which settlement has been arrived at through the payment to the mill owners "in kind," that is, by the development of the storage facilities of the drainage area, other than the mill ponds would supply, by joint action of the interested parties or by one or the other of those parties.

It was suggested to me by a case in which Mr. King is interested at the present time, in which I made some figures which tended to show that the storage developed upon the head waters of the stream actually benefited the owners who were suing for the diversion of water. Yet the owners succeeded in getting a small award. The litigation isn't over yet, and we have hopes at least that the award will be very small. It certainly opens a very interesting field of thought, and it seems to me that in some of these water diversion cases it is the natural and the most equitable solution of the problem. Whether we can get the lawyers and the courts to take that view of it or not remains to be seen.

I also want to ask Mr. Hale one question about the Nashoba privilege development. I understand that since the litigation the dam at this privilege has been rebuilt, and that power is being developed for a certain traction company. It might be interesting to know to what extent they actually do develop the privilege,— in other words, what wheel capacity has been installed at that point.

Mr. Hale. I do not know just what capacity of wheels they put in, but I understood that they spent $100 000 in the new dam, flumes, penstock, and so forth, there. It seemed, in general, a very large amount per horse-power on such a low fall as existed there, and I have been intending to determine the exact amount at a later date. I ought to have added, perhaps, in the course of my remarks, that Mr. Metcalf was one of the commissioners in the Nashoba case that was adjudicated. I think we should be very glad to hear any additional points in regard to that.

Mr. Metcalf. Mr. Chairman, perhaps there is one thing I might say in regard to that case. I think commissioners are usually rather wary about discussing cases which have been decided by them and the elements which weighed in the decision. I think it

is fair to say of this case, however, that the low head at this privilege was a factor in the decision.

The head was 8 feet, and at times of flood and in the high water season that head is cut down to about 6 feet, as I now recollect the figures. Of course, under these low heads the question of the regulation of the speed of wheels is an important factor in the proper operation of the generator, if electric power is developed. I should say that the regulation of the speed is much more difficult, and the variation in the speed becomes more serious in the operation of the privilege, and that fact weighed in the award which was finally made.

The valuations in this case on the part of the several experts ran from about $10 000 to $130 000, — that is the estimate of the damage due to this partial diversion,— the engineers for the Commonwealth giving estimates of from $10 000 to $15 000, and those for the company of from about $85 000 to about $120 000 or $130 000, as I remember the figures. The award was $25 000.

Mr. Hale. I might add a word in regard to Mr. Barrows' statement about storage. Some two years ago that matter of storage was taken up in New York, with reference to storage basins on the Batten Kill and other rivers, with the possibility of ascertaining if the floods at Troy and at other places could not be reduced by arranging such storage.

I attended a hearing before a commission at Albany, and it looked at that time as though the prospect was very good for something being accomplished. The commission was inclined to take the matter up, investigate it, and build some storage basins, and would coöperate with the mill owners, to the extent that the state would pay a certain percentage. I don't recall now whether it was 40 per cent. or 50 per cent., but it was something like that. The mill owners would pay in proportion to their power — or fall. They had a few hearings, and I think the matter was then declared unconstitutional, in regard to development along that line, — that the state couldn't go into it,— and the matter was dropped.

I understand that since that period they have been taking it up again. The mill owners on the Batten Kill are now agitating the question of building storage basins. I have been formulating an arrangement by which a company might be formed, so that

an agreement might be made by the various parties to do something and bear proportionally the expense. Whether it will come to anything or not, I don't know.

Mr. Metcalf. Do you chance to know, Mr. Hale, whether it is a fact or not (I believe it is a fact) that on the Blackstone River —or on one of the streams flowing into it — that very thing has been done by the Draper Company or some other mill owners?

Mr. Hale. Storage?

Mr. Metcalf. Yes; by the construction of the Echo Lake dam.

Mr. Hale. I don't happen to know of that.

Mr. Metcalf. I think that it was the case that the mill owners coöperated and built this dam for the storage of the water, and that the cost was met by the various mill owners. Whether they all entered into agreement or not I do not know, nor do I know the expense involved in the work.

Mr. Hale. The question on the Batten Kill in regard to the mill owners was in what way they should be assessed. The natural way would be in proportion to the fall, although in case of some of the falls which were not fully developed, or were undeveloped, the parties felt as though they shouldn't pay a proportional amount. That would be something to be agreed upon among them.

Mr. W. C. Hawley.* Mr. President, as a matter of interest along this line I might say that when the city of Troy was considering the Batten Kill supply, some twelve years ago, it was found that in order to get the water to the distributing reservoir a ridge had to be crossed, and that there would be 10 000 000 gallons per day with an available head of something like 200 feet from the top of this ridge to the distributing reservoir. It was proposed then to develop this power and supply electric power to the various mills whose horse-power had been reduced by the diversion of this water. The scheme was worked up to a point where we considered the legal end of it, and it was decided that it couldn't be done under the existing laws of the state of New York, and for that reason was given up.

It would have more than replaced all of the power which was

* General Superintendent, Pennsylvania Water Co., Wilkinsburg, Pa.

taken from the mills, and would have given the city of Troy considerable power available for street lighting, and so forth.

MR. MAIN. In answer to Mr. Metcalf's question I would say that during the time the Worcester cases were under consideration —the Kettle Brook cases—it was suggested that that very thing be worked out and presented in evidence, and Mr. Freeman C. Coffin was employed. He did a considerable amount of work along those lines, but counsel for the city decided that it wasn't proper to put it in, so it was dropped. I understood at that time that in England it was lawful to pay in kind,— to build a compensating reservoir and to supply as much water as had been taken away in that way, but that it couldn't be done in the state of Massachusetts.

MR. KENNETH ALLEN.* Mr. President, several years ago projects for an additional water supply for the city of Norwich, Conn., were taken up. I am very sorry that Mr. Chandler is not here to read his paper, because I thought, being fully acquainted with the circumstances, he would probably touch on the question of compensation in kind in that connection.

The firm to which I belonged at that time made an investigation and recommended compensation to the mill owners below the proposed reservoir by paying in kind. There were a number of mill properties below the watershed that would be affected, but we showed to our own satisfaction — if not to that of the mill owners — that they would be bettered by the improvement.

As a matter of fact, this proposed supply was about 7 000 000 gallons a day, while with the old supply they were getting about 2 500 000, and we considered that, with the natural growth of the town, the city would be justified in expending the amount of money necessary to provide the larger supply. As a matter of fact their bond issue, I understand, was limited to a certain amount, which wouldn't quite pay for this, so that the works were never built.

I was very much in hopes the matter would come to such a point that it would be shown whether this could be put through. I understand the mill owners made a claim for damages of about $100 000. That added to the cost of the works would probably have been prohibitive.

* Division Engineer, Baltimore Sewerage Commission.

There is one question I should like to ask, and that is whether there has ever been any consideration of damage to a lower water right on account of *pondage*, this being in the nature of a damage rather than a compensation; that is, pondage, rendering uncertain the supply of water to a lower mill, would naturally act as a detriment rather than an advantage in operating the said mill, for which damages might be demanded.

MR. MAIN. I was going to add that too much weight could not be placed upon the use of very definite terms in the division or appropriation of water rights to determine the amount of water to be used by different parties upon the same privilege.

Two very interesting cases have recently come to my notice, one of which I have worked out and the other one I have not been able to work out yet.

A short time ago I was called upon to see if a certain party was using more water than properly belonged to him. The terms of the deed were something like this:

It was dated in 1872. It stated that the mill connected with this privilege had the right to use as much water as would be required to run 200 cotton looms, and the complement of other machinery, on a wheel not less efficient than a good breast wheel.

Fortunately, the shafting had not been removed from the mill and I was able to determine from that and from a workman who had been in the mill some forty years, the width of the looms used and the kind of goods produced. From this, I determined how much machinery was required, and how much power was required to run it, and after determining the efficiency of a good breast wheel in 1872, I was able to determine the amount of water to which the privilege had a right.

In the other case, the deed was written in 1861; the party had a right to use as much water as would be required for a 10-set woolen mill for power and manufacturing purposes.

To determine the amount of water, it was necessary to ascertain the greatest width of card used in 1861 and to work out the organization of a 10-set woolen mill, based upon such width of card, and to determine the maximum amount of power required for a 10-set woolen mill and the amount of water required for power and for manufacturing purposes for the same.

Deeds written as indicated above are very indefinite and when written to-day should designate the amount of water in cubic feet per second to be drawn, so that there will be no question about the amount.

Chairman King. Mr. Metcalf said that the statute required that the dam be built above the privilege, so there is no question about providing for the storage. The question is of the offset for damage. Another question arose in that case — perhaps Mr. Metcalf looked into it — where different parties were taking water from the stream, one below the other, of course, where they formerly all drew water in the daytime. Then, by a change, the water went into the hands of an electric light company, and they use the water in the night. Whether there is anything to be said upon that subject, — perhaps Mr. Metcalf looked into that question.

Mr. Metcalf. I don't know, Mr. Chairman, that I have very much to add on that matter. It seems to me the question of pondage — the same question to which Mr. Allen has alluded — is a very vexed one, — one on which we haven't had very definite decisions, beyond the fact that the courts have ruled that reasonable use on the stream should be considered. Just what reasonable use of the waters of a stream, or just what that term means, is, perhaps, a little vague. In the case to which Mr. King refers, I stated in my report:

"It is evident from the small flow of this stream during midsummer, that there are times when substantially the entire twenty-four-hour discharge may be impounded within the mill pond of the electric-light plant and utilized during the evening hours of peak load at the plant. Under these circumstances, since the mill pond of the next privilege is probably considerably smaller than this mill pond, and hence would not be able to store the entire quantity let down at night by the electric-light plant, and thus make this water available for operating purposes upon the following day, — the court would probably construe such storing of the entire quantity of water flowing in the stream and the use of it during a few hours in the evening when other manufacturers' plants were shut down, as unreasonable. Were this view taken, the town might be enjoined from the use of its mill pond for its

own best advantage, and the power which it might derive from the stream for its own use might thus be considerably reduced. If, on the other hand, the stream flow during the day were sufficient to take care of the needs of the mills, or if these mills had mill ponds of sufficient capacity to enable them to store during the dry season the entire twenty-four-hour flow of the stream, the town could doubtless avail itself of its mill pondage to the most advantageous limit."

I assume that where the character of the use has changed materially,— as in the case of an electric-light plant which has been established on a stream, and which wishes to use the water during hours only when the mills are virtually closed, as against the former use by a mill which operated twenty-four hours out of the day, — that the court would not hold that the newcomers would be entitled to so radically modify or change the regimen of the river for their own benefit as to seriously affect the operation of the privileges below them.

The question depends upon the size of the mill ponds above the privileges, as well as upon the quantity of water which is flowing in the stream. No court, I assume, would permit an electric-lighting company, for instance, to hold up all of the water during the daytime, to the disadvantage of the mill owners below who wanted to use it throughout the day, unless the mill owners below had mill ponds, which would make it possible for them to store the water, or the major portion of it, which was let down in a few hours during the night by the electric-lighting company.

It occurs to me to say just one word further, along the line to which Mr. Hale and Mr. Main just alluded, — the exact definition of terms. Mr. Main has just referred to the term "head." We recently had an interesting case in Maine, in which the word "head" was a matter of dispute. In this case a privilege had been sold, with the understanding that 17 feet of head were to be had at the privilege at a certain time, for the use of log drivers. The question then came as to how that head should be measured. It was the head from the bottom of the dam, was it not, Mr. Hale?

Mr. Hale. Yes, sir.

Mr. Metcalf. The experts on one side contended that, according to usage on lumber-driving streams, head was measured

at dams built for storing water for log sluicing and driving purposes from the sill of the dam or bottom of the waste gate, to the surface of the water above the dam, unless there was back water at the dam, and that the bottom of the dam was at this point, the structure below this point being in the nature of a sub-foundation. The experts for the other side contended that the bottom of the dam was the bottom of the lowest log in the structure, and they actually sent a diver down to get the elevation of the underside of the bottom log in the dam.

Of course, counsel for the plaintiffs took the view that, under the latter interpretation, out of 17 feet of head they would get something like 12 or 15 feet of mud, instead of water. It certainly was not water, nor was it available or convertible into power.

MR. J. H. COOK.* I have listened with a great deal of interest to the remarks of the various gentlemen, and some of the things which were referred to had considerable interest for me. I suppose I can't talk of these things in their proper order, but I noticed that some one spoke — Mr. Barrows, I believe — about state regulation of water supplies, or control by the state of water supplies.

In the state of New Jersey at present, under a statute passed last winter, there is a commission appointed which claims to exercise control over all the waters of the state, and expects, according to the ideas of the people of the state, to build reservoirs and perhaps sell water for the supply of various towns in the state. Whether the state may sell water or not for that purpose of course has not been determined by any suit as yet.

The commissioners also intend, according to the terms of the bill, to cause all parties that divert water from the streams to pay to the state a certain amount per million gallons for water so diverted. The state, in fact, believes, or the legislature believes, that the state has absolute control over the water of the state.

I have heard, too, some of the speakers speak about compensating reservoirs. I know of a case — I did not suppose that they were very uncommon — in the state of New York. The Consolidated Water Company of Utica, N. Y., maintains a compensating reservoir on the upper waters of the West Canada Creek, and through agreement with the mill owners below, said company

* Hydraulic Engineer, Paterson, N. J.

passes out from this reservoir (which is on the upper Black Creek,—a tributary of West Canada Creek) the natural flow of the streams which flow into this reservoir, plus the amount the water company diverts at Hinckley, a point some miles down the river. They have only operated the thing about a year, and there has been some little friction already.

Somebody spoke about compensation in kind, and it made me think of a case in New Jersey, which perhaps may be familiar to some of the gentlemen now present. The water of the Pequannock River above Charlotteburg was taken by the city of Newark, which contracted with the East Jersey Water Company to build works for a water supply for Newark. On this river were some small streams upon which dams and reservoirs were built. After this work was completed, that is, after the storage reservoirs were built, the quantity of water that passed down the river into the intake reservoir was practically constant, changing the flow of the river, which had formerly been in the driest times two or three millions of gallons or less daily, and a very large quantity in times of freshet. A mill owner sued the company that built these works because he said they interfered with the natural flow of the stream, and the mill owner recovered damages; and presently, a few years afterwards, he brought another suit for interference with the flow of the stream since the time he recovered before, and again recovered damages. Then the water company got sick of that game and bought the property, which it was claimed was injured, although it appeared to some persons to have been benefited.

Mr. E. L. Grimes.* Mr. President, I have been very much interested in the discussion before the meeting, as we are at present trying out some of these cases in Troy, N. Y., and especially the one that has been referred to. One of the important points with us is in regard to compensation for the diversion of part of the water from the stream. A question which I think Mr. Main did not touch upon in regard to substituting a steam plant for the power diverted, is in regard to its location, distance from the railroad, or convenience in getting to the point. Now, the cost of substituting steam at a point that is very difficult to

* Chief Engineer, Troy, N. Y., Water Works.

get at would be much different from that at a point easily accessible and would, it seems to me, make quite a difference in the question.

Another question that is brought up is in regard to storage: A large mill owner upon the stream below our diverting dam has, above our diverting dam, quite a large storage reservoir. In certain seasons of the year, if he happens to be short of water, he lets this storage reservoir run down, and of course it benefits the parties between the storage reservoir and the owner's mill.

The point to decide is, What rights to the use of these stored waters have the mill owners who do not own the storage reservoir, or who depend entirely upon the flow as it is let down by the party who owns the storage reservoir? I understand that the mills intermediate do not pay any part of the maintenance of the storage reservoir, and I suppose they could not force the party to maintain the dam there or let the water down at certain times. Another question is, What value is that storage reservoir to the parties who do not own it?

We have also another system on which the riparian rights have been settled. It seems to me it would be interesting to know, or to have tabulated in some form which would be convenient for comparison, the awards of the damages in similar cases; and, in view of that, I have tabulated the cases relating to water powers that have been settled.

TABLE SHOWING AWARDS MADE IN 1903 FOR DAMAGE TO WATER POWERS BELOW DAM OF TOMHANNOCK RESERVOIR, TROY (N. Y.) WATER WORKS.
Drainage area above reservoir dam, 67 square miles.

	Remarks.	Total Award.	Award per Sq. Mile per Foot Fall.
About 1 mile below dam,	Old flax mill not used for several years, also old saw mill. Total fall, 18 ft.	$4 500.00	$3.75
About 1 mile below dam,	Farm area not given. Grist mill rather old. Total fall, 18 ft.	12,000.00	10.00
About 2 miles below dam,	Farms and water power undeveloped. Total fall, 150 ft.	22,000.00	2.20

	Remarks.	Total Award.	Award per Sq. Mile per Foot Fall.
About 3 miles below dam,	Undeveloped power and farm of 240 acres; 180 acres affected. Total fall, 40 ft.	16 000.00	5.97
		$54 500.00	$3.55

Mr. Hale. Mr. President, in regard to the use of the ten- and twenty-four-hour power, there is considerable attention being paid to that now, I think, by the various companies. When parties were attempting this year to obtain a charter for a dam at Reeds Ferry on the Merrimac River, the counsel for the Amoskeag Manufacturing Company was very insistent that there should be included in the charter the clause that no interference should be asked for in regard to the customary hours of running the mills at Manchester, or at any locality on the river above this point, as far as Lake Winnepesaukee.

They felt as though if this dam was to supply power twenty-four hours or ten hours, or whatever it might be, they might have some rights to insist on the natural flow of the stream, and they didn't know what might arise. These manufacturers wanted to protect themselves in that way, so they asked to have that clause put into the charter, which was agreed upon, as the probability of interfering with the mills above would be very remote.

I think in regard to the use of ten-hour and 24-hour power there is a case of Mr. Whitney at Winchendon in which Mr. Main and Mr. Coffin were consulted. I don't know how that was decided by the courts, but I think Mr. Main can tell us about that.

Mr. Main. I have the result of that case in mind. Mr. Whitney owned a large reservoir, and formerly had two water wheels, — one for his cotton mill and one for his machine shop,— and ran them both during the daytime. Several years ago the cotton mill ceased running, and the wheel in that mill stopped, and he used only the wheel in the shop. A few years ago he conceived the idea of using the wheel in the cotton mill for electric-lighting purposes, to light the town, and ran that during the night. He had a large reservoir to control the water and the owners below

him had very small ones and whatever water went through the cotton mill wheel at night got past their dams. They brought suit to make him stop using the water at night, and to require him to use it, they said, in the customary and ordinary manner, which was ten or twelve hours a day. Mr. Coffin and I found that approximately the same amount of water was used in the twelve hours of daytime as during the twelve hours of night-time, or about as the natural flow of the stream. Every one connected with the case for the mill owner thought he had a very good case, that the mill owners below could not make it necessary for him to use his dam and pond for their benefit, storing the night waters so that they could use it all in the daytime. We felt if he wanted to shut down his shop he could do so, and if he did the water would flow over his dam uniformly twenty-four hours a day.

The case was tried before a master, and the master found that Mr. Whitney must cease to use the water in the night, and use it only in the daytime. Mr. Whitney paid no attention to the finding of the master, and kept on running day and night. The court overruled the finding of the master, and found that Mr. Whitney had the right to use the water twenty-four hours in the day, provided that he used it as it came down to him and about as the natural flow of the stream. So that it turned out finally as we thought it ought to and as common sense would indicate, and everybody was happy except the mill owners below.

Mr. A. A. Reimer.* Mr. Chairman, that brings to my mind the question whether underground waters have been involved in any of these suits.

Chairman King. Can any one give us any information on this subject? Wasn't that suggested in the Newburyport case, Mr. Forbes?

Mr. Forbes. Mr. President, I don't know as I can answer this question just at this point. The matter of a ground water supply and the proportion it bears or the effect it has in regulating the flow of a stream, and particularly the flow during a dry season, is of course a very important one. It perhaps becomes less evident upon the larger streams; that is, the total effect is not so great; but where a small drainage area is considered the result

*Superintendent of Water Works, East Orange, N. J.

may be very noticeable, due perhaps to the fact that we do not know the extent of the drainage area, from a ground water point of view, with the accuracy with which we know the surface drainage area. So that unquestionably in many cases on small drainage basins the tributary ground area may be very much larger, thus accounting for the unusually high flow per square mile during the dry season. Possibly that is not just along the line that the speaker asked his question, but that may explain it somewhat.

MR. GRIMES. Perhaps it would be of interest to know about a little experience we had in a claim of this kind. A farmer put in a claim for diversion of the water, on the ground that it prevented percolation of the water through his land. His claim was for $5 000. In investigating the matter we found that he had something over five miles of tile drain laid to keep his land dry.

CHAIRMAN KING. Will Mr. E. H. Foster, of New York, add something to this discussion?

MR. FOSTER. I hadn't intended to say anything on this subject, Mr. President, but I have taken down a few notes on points that interested me in the papers that have just been read. One thing that impresses me about these cases is the very wide diversion between the estimate of value of the power as made by the mill owner and the value placed upon it by the prospective purchaser. About 20 to 1 seems to be the usual ratio. I have a case in mind where it was just about in that proportion, and I think Mr. Metcalf mentioned another. Much depends upon the circumstances surrounding the cases, the condition of plants, and so forth. An owner usually is able to see ahead that his water power is going to be condemned, and he lets his plant run down for three or four years, oftentimes until it is practically valueless at the time proceedings are instituted for making an appraisal, and it is very hard to get at the conditions as they existed at the time when the owner really first began to let his plant run down.

It seems to me that this general subject is of sufficient importance to the members of this Association to consider the appointment of a committee. Nearly all of these cases are between municipalities and mill owners. We represent largely muncipalities. The mill owners are largely represented by members

of the National Cotton Manufacturers' Association. The membership of these two associations is chiefly drawn from the same part of the country. Hence, the members are naturally familiar with the same problems from their respective viewpoints. Furthermore, the abundance of water power and the tendency toward manufacturing, has naturally led to a great many disputes on this subject in New England — probably more up to the present time than in any other part of this country.

Why would it not be a good plan to have appointed a committee to approach the cotton manufacturers, and intimate that they should appoint a committee, and have these committees act jointly to get up a set of rules or recommendations for estimating the value of water power diverted or appropriated for various purposes, and generally to embody the ideas presented in various papers before this Association, before the American Society of Mechanical Engineers and the American Society of Civil Engineers the valuable contributions by the author of the paper under discussion, the works of Frizell and various other writers on the subject, and boil it all down to a simple set of rules, which could be applied to a great many cases?

These cases are usually brought before a court and the court appoints a commission, which is generally a lay commission, and they hear the testimony. The result is a great waste of time and expense, which is not at all justified by the amount involved.

I really believe it would be conferring a benefit not only upon the mill owners,— the small mill owners especially,— but also upon municipalities that contemplate changes in their water system, to have some definite rules which could be regarded as more or less authoritative, and with this object in view, Mr. Chairman, I offer the following motion:

"That a committee be appointed by the Chair, to approach the National Cotton Manufacturers' Association, and invite them to appoint a committee, these committees to act as a joint committee to draw up a set of rules to govern the estimation of damages to water privileges by diversion."

Mr. Charles W. Sherman.* Mr. Chariman, it strikes me off-hand, without opportunity to give much consideration to the

* Civil Engineer, with Metcalf & Eddy, Boston, Mass.

matter, that this committee would have a very difficult problem, to say the least, and might find it impossible to get any coöperation from the Cotton Manufacturers' Association, in which case they would be thrown back on us with nothing done.

I am inclined to offer, as an amendment to Mr. Foster's motion, that the committee be appointed as he suggests, but instead of asking the cotton manufacturers to name this other committee to act with them, that our committee be appointed to consider the practicability of such a joint committee, and the possibility of its obtaining results that would be of value, and, if they see fit, to confer with the officers of the Cotton Manufacturers' Association as to their ideas and their practicability and possibility. It is hard to put that amendment in form without rewriting it.

Chairman King. It would be a substitute motion.

Mr. Metcalf. Mr. President, if I might make a suggestion, I should like to ask Mr. Sherman if he wouldn't include in his motion that this committee should collect data relating to awards for diversion of water and water power. It seems to me that the most valuable work this committee can do, or will be likely to accomplish, will be to accumulate specific data regarding awards in such cases. There have been quite a number of suits, on different streams, growing out of diversion, and the members of this Association, I think, can bring the data relating to awards together and put them into the hands of the committee, if the committee had power to accumulate them.

I question very seriously whether we will be able to get the coöperation of the Cotton Manufacturers' Association, and even if we do, whether it will be very effective. Of course the courts will finally have to pass upon the question of proper damages, and it seems to me it is a pretty big task to place upon any such committee, whereas data could be accumulated comparatively easily.

Chairman King. Perhaps it is not quite in order for us to dispose of that before it is amended in the motion. Is there anything further to be said in relation to the appointment of this committee, or any suggestions? If anybody has any suggestion to make it is a good time now to mention it.

Mr. Sherman offers the following substitute for Mr. Foster's motion:

"That a committee of five be appointed by the President to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers' Association, or other organization of mill owners, leading to the formulating of standard rules and methods of computing or assessing damages for the diversion of water."

Does Mr. Foster accept this substitution?

Mr. Foster. I accept that.

Chairman King. Then, as Mr. Foster accepts this, this motion is now before you. Is there anything to be said on the motion?

The motion was put to vote and carried.

Chairman King. It is a vote and the motion is adopted.

THE SPRINGFIELD WATER WORKS.

BY ELBERT E. LOCHRIDGE, CHIEF ENGINEER, SPRINGFIELD WATER WORKS, SPRINGFIELD, MASS.

[*Presented September 11, 1907.*]

Mr. President and Members of the Association: In 1872, when the city took over from the Springfield Aqueduct Company the plant from which the water was supplied to the city, Springfield was situated in large part on the lower level along the river, on the plain upon which this hotel (the Cooley) is situated, and did not extend at that time to any considerable extent to the higher region. The population in 1870 was about 26 000, and the city had just reached the stage when more water was necessary. It was accordingly necessary, as one of the first acts of the city in its municipal rôle of water seller, to obtain a new water supply.

Several of the experts of the time were called and the various upland streams in the vicinity were studied, as was also the question of supply from the Connecticut River. At that time there was a report presented in favor of the Westfield Little River, the supply which the city is just now taking. This was found, however, to be too expensive for a city of 25 000 people. Cast-iron pipe was pretty high in those days, and there was a good deal of labor involved in getting the water out from the gorge.

As a consequence a scheme was developed by which it was planned to take water from several branches of Broad Brook, lying in the towns of Ludlow and Belchertown,— very largely in Ludlow, — and this was the water taken at that time. It was possible at a very reasonable cost to throw a couple of dams across the two small outlets of a large swamp and flow what is now known as the Ludlow reservoir, with an area of about 445 acres and with a possible capacity at high water of nearly 2 000 000 000 gallons. This, it was thought, would supply water for a considerable time. It had the added advantage that it stood some 160 feet, I believe, above the higher portion of the city, and although it was 12 miles

distant from Main Street, it was possible, with a 24-inch cement-lined pipe, to deliver a sufficient quantity of water under pressure to all parts of the city. Just at that time the city was growing eastward, or toward that supply.

That is, in general, the history of the taking of the Ludlow water. The supply from the first began to develop, in the summer time, unpleasant tastes and odors, and the records of the gate-keeper in those earlier days show that the water every year, from the very first summer, developed a green growth, which made the water very objectionable in appearance as well as for drinking purposes.

After several years, these disagreeable tastes and odors appearing each year for varying lengths of time,— some years for not more than a few weeks, and other years extending over two months or more,—it was found that the city would need more water, and in about 1890 or 1892,— I am not certain of the exact date,— another tributary was added to the Ludlow reservoir by means of a canal seven miles in length. It was hoped that this would not only furnish more water to the growing city, but would also cause circulation through the reservoir, improving the quality of the water and rendering the supply adequate for a longer period. This was done, and in fact from all I can learn from the records and from the testimony of the people who had to use the water before and since, it did make a considerable improvement, and the water was bad for a shorter portion of the year.

However, as time went on, the tastes and odors became more objectionable again, and in time the capacity of the supply was again inadequate, if we should consider the possibility of as dry years as had already been experienced, and the growing size of the city. In order to supply water during the time when the Ludlow reservoir was bad, three smaller ponds lying between the city and the Ludlow reservoir were taken, Chapin, Loon and Five Mile ponds. These ponds are in reality springs in a sandy soil, and they furnish a very clear, nice-appearing water. They are on a lower level than the main supply and consequently have to be pumped. These ponds cover, on an average, an area of about 30 acres each and have no feeding streams tributary to them, and but one of them has any outlet. It is, therefore, apparent that

they represent merely stored ground water, and their capacity is limited to that of the storage capacity of the surrounding sand. It has been found that the city could draw upon them for a little over 6 000 000 gallons per day during a period which will not exceed thirty or forty days, at the expiration of which the ground water of the ponds and the region about them would both be at a very low stage. They were particularly valuable in furnishing an exceptional quality of water at just the desired time, but their capacity was not quite sufficient to make up the total deficiency or to cover in extent of time the period of bad Ludlow water. Accordingly, the Jabish brook water was diverted about the reservoir, as is shown in the accompanying diagram, and was used directly from the small basin. While this was necessary in order to make up the necessary quantity of clear water, it was objectionable in that great care was necessary to prevent pollution, inasmuch as the water was used without having been held in storage even for a short time.

As the city continued to grow it was found that something would have to be done. A great many in the city did not attempt to use the water at all in the summer time; others filtered it, using a small house filter. This, of course, made an added item of expense to each consumer, and in general the quality was unsatisfactory. In addition to this was the fact that the time would soon come when there would not be water enough unless either additional storage should be obtained on the watershed or a new supply should be taken.

The history of the discussion over this problem is a long one, and there was a good deal of feeling on both sides, many feeling that Ludlow water, although not all it should be, could be made satisfactory, or at least usable, and that this should be done. On the other hand, those who looked into the future of the city thought that perhaps with the continued growth even more water would be necesssary, and that, on account of the necessity of large expenditure for the purification of Ludlow water, as well as the additional expense of further development, it would be better to go directly to some other supply.

After a number of attempts at securing legislation for various supplies, in the fall of 1905 all parties agreed upon a method of

procedure, which was adopted, and it has been carried into effect. That was, first, the construction at the Ludlow reservoir of a filter designed to remove the tastes and odors, or at least to help in the removal of the tastes and odors, during that season when it was objectionable, inasmuch as the water during the colder portion of the year was by no means unsatisfactory; and second, at the same time that this filter was ordered at the Ludlow reservoir it was voted to ask legislative permission to take for a new supply the waters of the Westfield Little River. In round numbers the total Ludlow sources have some 20 square miles of watershed, and Little River some 48 or 50. They are situated about equally distant from the city, the Ludlow source to the east and the Little River source to the west.

An added call for a new supply was made because of the insufficient height of the Ludlow reservoir. The hill section of the city has developed very rapidly, many higher points being now occupied than were at the time the Ludlow supply was taken, and as a consequence the need of more pressure was quite apparent. This, of course, could be obtained from a new supply, and probably obtained more cheaply, it was thought, than by raising the Ludlow supply to some greater height or by laying much larger mains.

This compromise plan was carried out successfully, the legislative permission for the taking of Little River was secured in April, 1906, a little over a year ago, and by July, 1906, the filter which was ordered in the November previous was in working order at the Ludlow reservoir.

Just a word as to this filter. The studies on the Ludlow water have covered a considerable period of time. In 1901 the state board of health, together with Mr. Percy M. Blake, operated experimental filters at the reservoir for about thirteen or fourteen months, and it was found that, with the exception of the summer period, the water could be treated very easily, but during the summer period the tastes and odors were never fully removed. Following this, in addition to many other experiments by the board of health, in 1903 Mr. S. M. Gray and Mr. G. W. Fuller were appointed by the Special Commission on Water Supply, who were to study this phase of the question, to look into the problem of a new supply. During that summer I was employed by these

engineers to study the Ludlow water, and during the Anabæna season twelve filters were operated. From no filter during that time was entirely satisfactory water secured. It was found that in the sand filters as operated the organic matter would clog the bed and an exceedingly disagreeable odor would be developed unless a rather high rate was maintained.

I will not go into these experiments, but following them the report was made that while the water could be purified, it would be by means of double filtration and with triple aëration, as it was found that it was the aërating of the water and the furnishing

FIG. 1. GENERAL PLAN SHOWING LOCATION OF LUDLOW FILTERS.

of sufficient oxygen to entirely remove the objectionable odors that was necessary to furnish an effluent of desirable quality.

As a consequence, when Mr. Allen Hazen was called upon to furnish a filter that should be both cheap and very efficacious in its action, he was confronted with a problem that I think he was hardly expected to solve.

This filter as designed was to be of sand, put in by analysis only and not by washing, directly from the sandbanks near the site of the filter. The water was to be pumped upon the beds and the usual height of the reservoir used for pressure in the city as heretofore. These filters cover practically four acres in extent and are of a depth of five feet of sand over tiled underdrains laid directly on the subgrade, with no concrete or other bottom. These are all connected into a main central drain, which carries the filtered water out to the clear water reservoir or basin, which, before the construction of the filter, was the controlling basin for the city. The filter was operated through the season of 1906 and furnished very satisfactory water. It is designed to give aëration before the water is delivered to the filter bed, so that even though the regular reservoir water is highly charged with organic matter and has but little dissolved oxygen, it will be thoroughly aërated. Following the filtration, it falls from the lateral drains into the central drain and again from the central drain into the basin, giving in each case an additional aëration following filtration. This was to rid it of any odors which would pass the filter, and also give a well-aërated water for use.

In addition to this the beds are operated intermittently, that is, for sixteen hours or longer if necessary to furnish the supply, but on an average of about sixteen hours each day, and then the beds are allowed to rest and to have air drawn through them so that the sand will become filled with air and in this way supply additional oxygen to the beds. In this the lesson, learned from the earlier experiments, that aëration was one of the essential features of the purification of this water, was made use of.

During the season of 1906 Mr. G. H. Shaw was in charge of the operation, and the results were quite satisfactory. However, at no time during that year did we have the amount of Anabæna (which is the bugbear of the reservoir) that we have had in a good

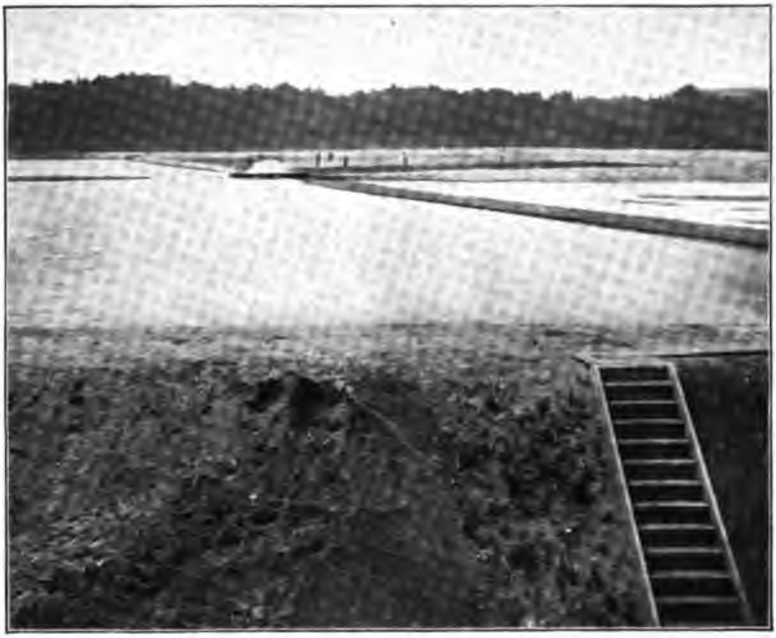


FIG. 1. GENERAL VIEW LUDLOW INTERMITTENT FILTER, SHOWING ARRANGEMENT. AËRATOR IN CENTER. BED IN DISTANCE IN PROCESS OF CLEANING, REMAINING THREE BEDS IN OPERATION.

FIG. 2. LUDLOW INTERMITTENT FILTER. LOOKING ACROSS ONE BED, SHOWING SAND EMBANKMENT WHICH SEPARATES BEDS, ALSO AËRATOR.

FIG. 1. LUDLOW INTERMITTENT FILTER. CENTRAL CONCRETE DRAIN AND WOODEN FLUME. POINT AT WHICH ALL FILTERED WATER LEAVES FILTERS. THE FLUME CARRIES THE WATER 100 FEET OUT OVER OPEN FILTERED WATER BASIN TO POINT THAT IS DEEP ENOUGH TO ALLOW FREE FALL OF EFFLUENT FOR FINAL AËRATION.

FIG. 2. LUDLOW INTERMITTENT FILTER PUMPING STATION AND LABORATORY. SHOWS 36″ INTAKE.

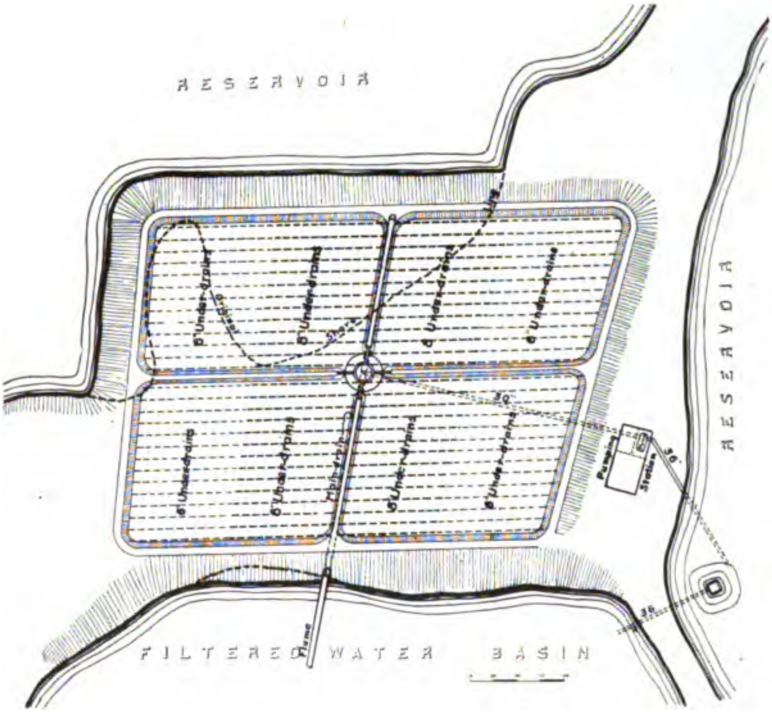


FIG. 2. PLAN OF LUDLOW FILTERS.

many seasons past, so we were afraid that perhaps we had not had representative results and that there would be seasons to come when the water could not be successfully handled. During the present season Mr. C. F. Story has operated the filter and has had some more difficult water to handle. The amount of Anabæna has been very much higher in the reservoir, and the amount of Uroglena at one time was much in excess of any we had before. The duration of the epidemic, however, was not as long as it has been in past years. However, at all times very satisfactory water has been produced. It has not always been entirely free from tastes and odors as it entered the basin, but it has been substantially free, and it has furnished a water which has been quite

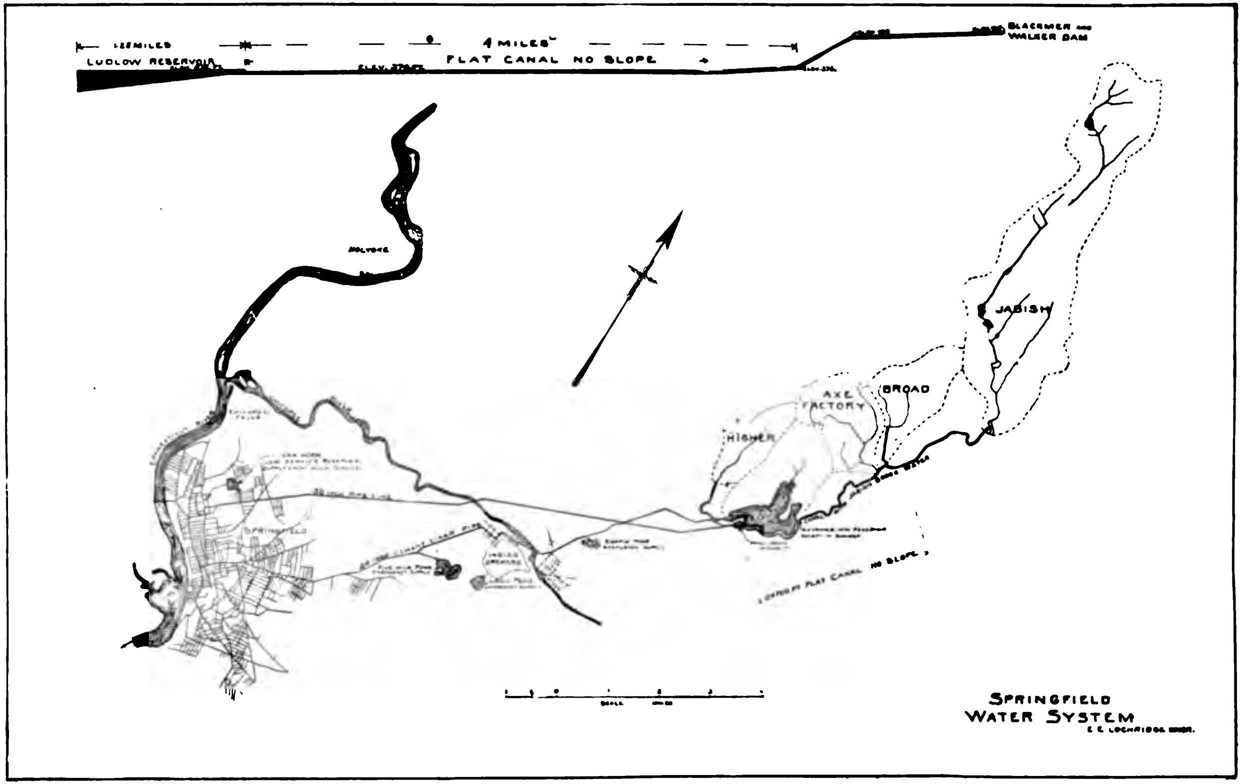


Fig. 3. Ludlow Supply, showing Watershed, Canal System, Pipe Lines and Location of Emergency Supplies.

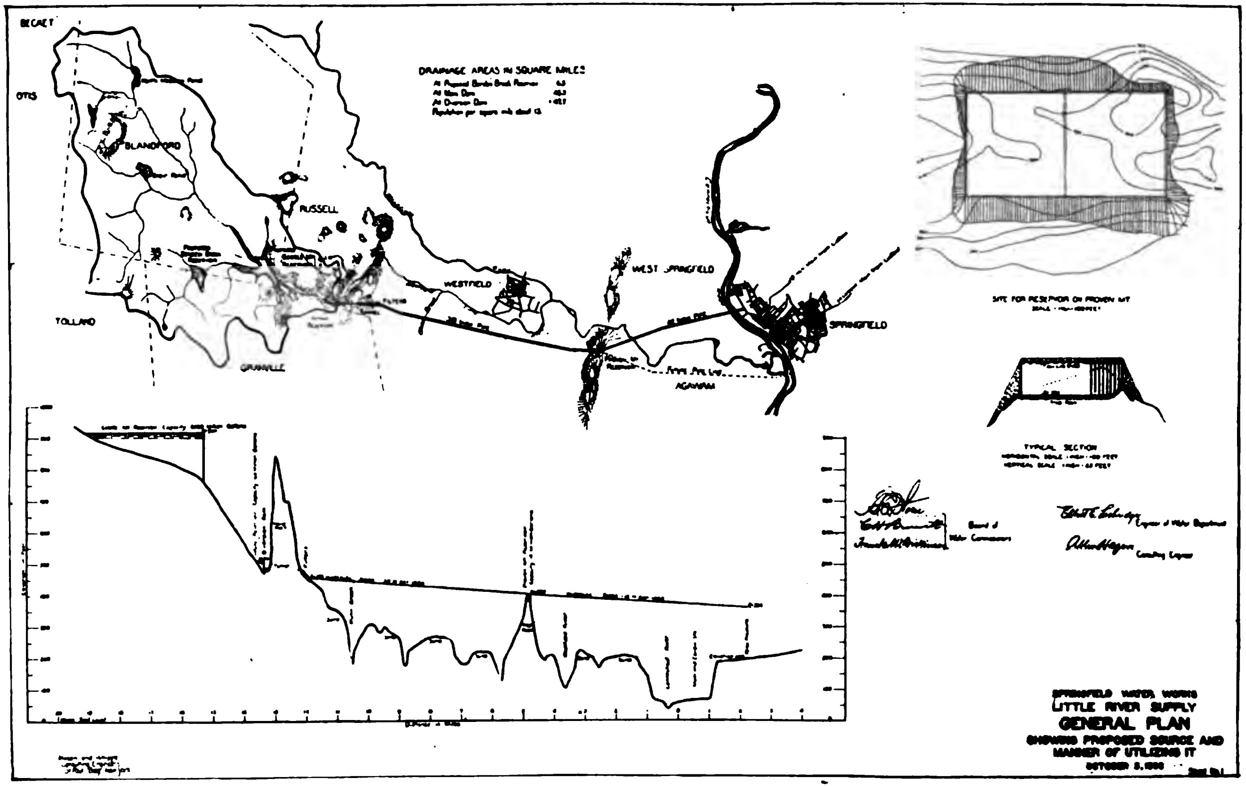


FIG. 4. LITTLE RIVER SUPPLY.

acceptable, I believe, to the consumers, and far more acceptable than any water we have had in any summer for a great many years.

With this filter thus established between seasons, and something done for the Ludlow water, the city was united in asking for a new supply, and with the acceptance by the city council of the Act authorizing the new supply, the work has been started to bring into the city, from an entirely separate source, in an exactly opposite direction, a supply which will be complete in every way.

It is planned to bring this in with a pressure of about 140 pounds on Main Street and about 70 in the hill section, which is 130 feet higher than Main Street.

This new supply has several features which are very desirable in a city system and which are not present in the old supply. It is taken from a very sparsely settled region; I believe with about 13 inhabitants per square mile. The region is mountainous, and the diversion of the water is from a gorge into which no road has ever been made, unless it was a logging road at one or two of the more accessible points, but a large portion of the gorge has never even been wooded on account of its steep nature. The sites for storage on the main stream are excellent. On the Ludlow system the water is all diverted by means of a long flat canal, and the main storage, the Ludlow reservoir, has practically no watershed of its own. While at present the requisite storage will be obtained from reservoirs on tributaries, a site is available which will supply enough water ultimately to supply the city until it shall become three or more times its present size. There are sites for filtration of the entire supply without loss of head or pressure in the city, as would have been necessary had the Ludlow supply been filtered without pumping. There is also within 4½ miles of the city a site for a distributing reservoir.

At the present time, when an excessive draft is made on the present system, we have a very considerable loss in friction on two main pipes of between 11 and 12 miles in length; while with the new system we will have a reservoir which will be near enough, or at least much nearer than the old supply, so that a fire or other excessive draft may be maintained without great loss of pressure.

There will be several other features of the new supply, which is to be put in at an estimated cost of a little over $2 000 000. This

PLATE III.

LITTLE RIVER SUPPLY — GORGE SHOWING NATURE OF STREAM.

is to be one of the few supplies, in this region at least, which will be taken from a mountainous source and filtered before it is used, the filter to be constructed before any water is taken. Filters have been built for supplies which receive more or less sewage, but as far as can be determined, this supply receives no sewage whatever, and, with the sparsely settled country, very little pollution of any kind.

At the present time, storage will be provided on one of the tributaries to the stream, and in this storage it will be possible to secure something like 2 000 000 000 gallons of water, with an area of only about 190 acres, making a much deeper reservoir for the storage than in the present system. The diversion dam, for which, together with the tunnel, the contract has just been let, is to be of cyclopean masonry and is to rise about 50 feet above the bed of the stream. The tunnel, 4 530 feet in length, will bring the water through the mountains to the filter site, from which a steel pipe will be carried across a very open country with but little ledge, and across land that is very largely sand, to the distributing reservoir on Proven Mountain, where a sufficient quantity can be held in reserve to equalize the fluctuations in the demand for water in the city. An additional feature will be the Connecticut River crossing and the connection with the city's mains.

An additional problem which the city has had to meet is that of its piping in the city. The supply coming from the east was brought in first through the residential section, and the mains were lessened in size as they approached the Connecticut River. Bringing in the supply from the west will necessitate the connecting of these mains in some way that the pressure may not only be properly maintained, but water provided for the city of the future.

There is a large amount of old pipe in the streets, and there is a large part of the city which is not at present gridironed, that is, there are no connections through to the neighboring streets. For example, Main Street is supplied with a 16-inch pipe running the greater length of the street, while Water Street (the next street toward the river and the one adjoining the river) is not supplied with any high-service pipe at all, while the side business streets extending off from Main Street are supplied only with small pipes

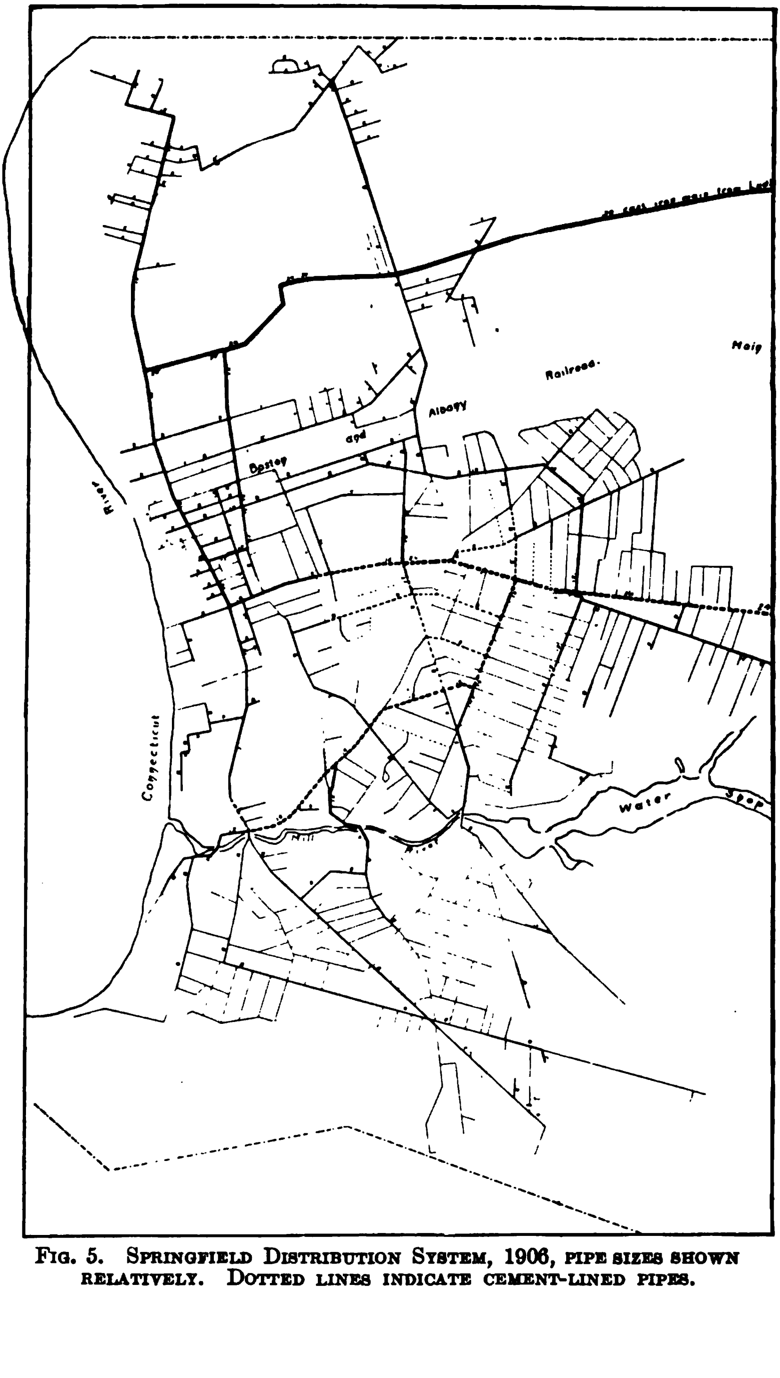


FIG. 5. SPRINGFIELD DISTRIBUTION SYSTEM, 1906, PIPE SIZES SHOWN RELATIVELY. DOTTED LINES INDICATE CEMENT-LINED PIPES.

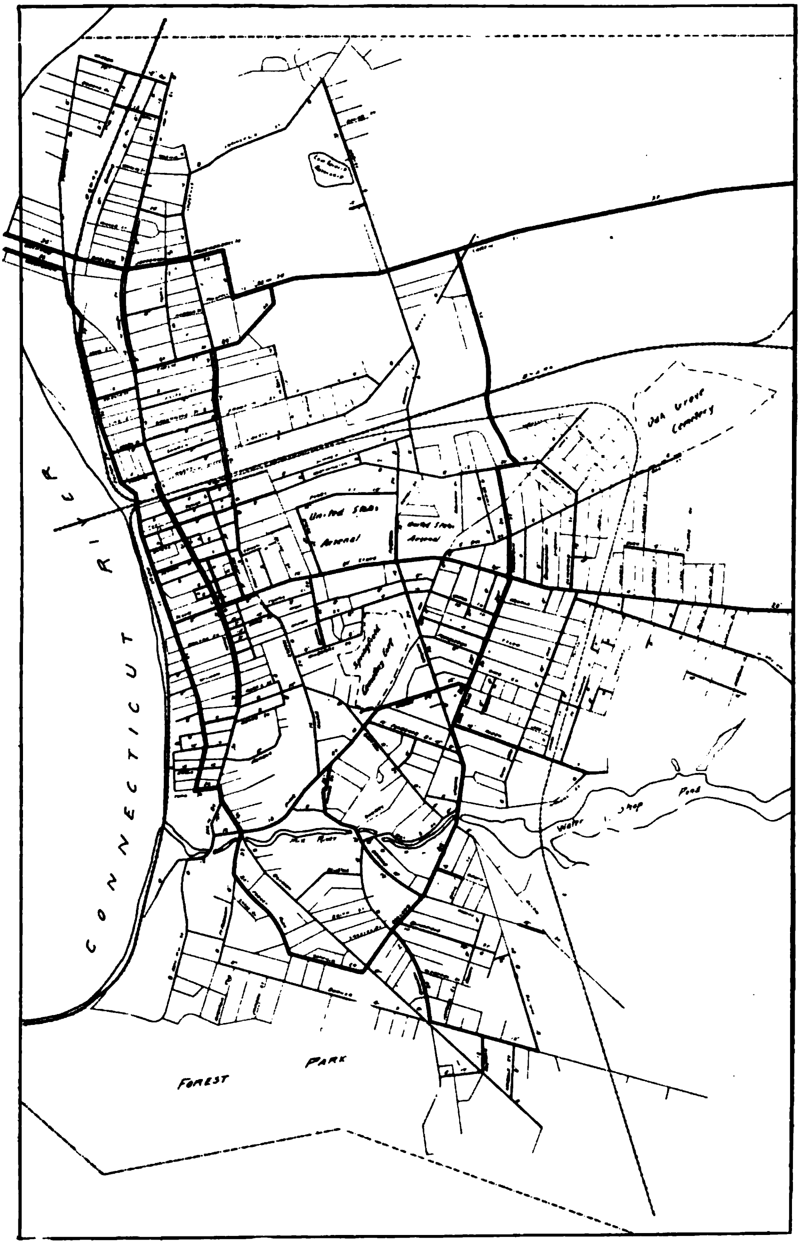


Fig. 6. Springfield Distribution System, showing circuit of large pipe around city. These changes now being made, about 20% having been completed in 1907.

which lead merely to dead ends at the end or middle of the block. It is necessary, therefore, in order to get the best system for the city, to reconstruct, or to bring in some manner, pipes to these streets, of sufficient size for fire purposes. This has been no small problem.

Mr. Hazen and Mr. John R. Freeman have both discussed this matter with us, and the matter was placed with Mr. Hazen, who secured Mr. R. D. Chase, who spent some months in studying the question of the proper fire service for the city and the proper distribution of the mains.

I will show you on the screen something of the problem which they had and the means which has been obtained of furnishing a good fire service to all parts of the city. (See Figs. 5 and 6.) This has been, or will be, accomplished by a belt main line about and through the main portions of the business and residential sections, a little over seven miles in length, which will be from 36 inches in diameter at the largest point to 24 inches, and at no point smaller. This will furnish the feeder which will draw water from either east or west, as may be needed, and deliver to any portion of the city the water under the full pressure, from which it can be taken into the smaller pipes and gridironed as may be needed.

This work of rebuilding the distribution system is well started, and this year considerably over $100 000 is being put into the improvement on the distribution system alone, largely in the starting of this circuit and in the extension and connection of the mains where it is necessary in order to provide for the new conditions.

DISCUSSION.

President Whitney. Mr. Lochridge's paper is now open for discussion. We should like to hear from Mr. Hazen.

Mr. Allen Hazen. Mr. President, ladies and gentlemen: I am glad to have an opportunity to add a few words to what Mr. Lochridge has said about the Springfield water works.

Mr. Lochridge has spoken of the Ludlow filter which was put in service at the beginning of last summer. I don't think it is quite fair to say that we built this filter. The filter was half built by nature before our work was started. It must have been some kind

foresight of Providence that put 100 000 yards or so of filter sand and gravel close to the Ludlow reservoir, and in fact partly in it, all ready to be tipped over with a steam shovel and made into a filter of the kind which you will see when you visit it. That was substantially the condition at Ludlow, and it was a novel condition, and we were able to utilize it fully for the benefit of the city.

There is another matter about the construction of this filter. It was built to a considerable extent in winter. The work was decided upon and authorized late in November. The filter was finished and put in service early in July following, before the worst summer condition of the water in the reservoir. And I want to say right here that the credit for building so large a filter in so short a time, and partly during winter months, is due to Mr. Lochridge and to Mr. Stone, the chairman of the Board of Water Commissioners. There was some steering from New York, but the pushing that enabled the filter to be built in so short a time was given by the two gentlemen named.

Mr. Lochridge has spoken of the long-continued experiments upon the treatment of the Ludlow water by Mr. Blake, and by Mr. Gray and Mr. Fuller, and by the state board of health, and he spoke of the fact that these experiments did not lead to a method of treatment that was at once economical and sufficient. It is true that the water was successfully purified in some of these experiments, but only by the use of double filtration under conditions which would have meant a very large expense for the construction and operation of a plant.

Ludlow water is pretty bad. I don't think that I need enlarge upon that. When we were at a legislative hearing some years ago, we told the committee that, as far as we knew, Springfield had the worst water supply of any considerable city in the state.

I speak of this to show that the problem which was considered in the experiments was a difficult one and a novel one. There were conditions that had not been met before, and it is not surprising that the first experiments did not lead to entire success with it.

And I wish to state at this time that while these experiments did not develop a sure and economical method for the complete purification of Ludlow water, they did serve to lay the foundation

for the method afterwards adopted; and I am glad of an opportunity to put this fact upon record to-day.

These experiments, in the first place, served to demonstrate that some methods and processes, which otherwise certainly would have been considered, would not succeed in the treatment of Ludlow water, and they served to give a good idea of the nature of the water and of how it acted under various conditions, and suggested the lines of modification of the treatments that were tested that would be most likely to prove successful.

And in studying the question some help was derived from the knowledge of sewage purification works. The organic matter that is most troublesome in this Ludlow water is chemically more or less like the organic matter in sewage, and it seems to be capable of being removed by the same methods. Sewage contains more organic matter than Ludlow water even at its worst, and a study of the methods of sewage purification which have successfully removed organic matters was of material aid in arriving at the design adopted at Ludlow.

The Ludlow filter as constructed had no direct precedent. It was to some extent an experiment. It was certain that it would make the water a good deal better, but it was not certain just how much better. The filter, therefore, was an experiment; but is differed from the experiments that went before in that it was conducted on a much larger scale and the effluent was put into the service pipes, and the people of Springfield were, therefore, made parties to the experiment and were able to judge of the results that were produced. And these results have greatly exceeded our expectations.

The Ludlow water is purified by this filter to such an extent that if quality were the only consideration, the people of Springfield would, I believe, be satisfied with water of the quality that they have received since the filter was put in operation. But the amount of water that can be drawn from Ludlow is limited. Springfield is growing rapidly and will certainly need much more water than is now used. In a wet year, or an average year, the Ludlow reservoir is able to maintain the supply that is now taken, but in a dry year it would be entirely unable to maintain that supply. Fortunately, in the last few years, since the consumption

has become so great, there has been no very dry year. Further, the pipes from Ludlow to the city are too small; the storage capacity is hardly enough; and if the supply were to be continued in use, new reservoirs, new filters, new pipe lines to the city, and, in fact, substantially a whole new plant would be required, as was conclusively shown by the report of Messrs. Gray and Fuller upon the Ludlow water. And this new plant would cost almost as much as the supply from a new source that is proposed.

Mr. Lochridge has told you about the Little River supply which has been authorized and upon which work is just being started. The design of this supply has presented some questions of the greatest interest. One of these is as to the most desirable pressure or elevation at which to deliver the water in Springfield.

Most of the Little River watershed has a great elevation. The main dam, which it is proposed to build sometime in the future, will have its flow-line some 900 feet above tide. It is physically possible to bring the Little River water into Springfield at any pressure that might be desired. It would certainly be possible physically to bring the water in with a pressure of 300 pounds per square inch, although it would cost a great deal of money to secure such a pressure.

The question to be determined was what pressure would be most desirable, all things considered, and taking into account the added expense involved in securing additional pressure. And there was also the question as to whether the city could best be served in two service districts, with high and low services, or whether it would be better to combine all in one system, with a moderate pressure in the higher parts and a rather high pressure in the lower parts of the city. Mr. Lochridge has already spoken of this problem of arranging the distribution.

The old part of the city along the river bank is but little elevated above it. Most of the larger and higher buildings of the city are in this low, flat area. Back of this area are bluffs of sand, with steep sides. The tops of the bluffs form a level plain of sand, extending back for miles, with here and there a valley cut by a stream or a rise of moderate elevation above the general level. On this sand plain the city has grown rapidly in the last years, and the greatest growth is now upon it.

There was a good deal to be said in favor of the proposition to have two separate services, a high service for the elevated plain, and a low service for the river bottom; but the arrangement of the piping could be more conveniently and cheaply made for a single system, and the single system unquestionably provided best for the concentration of large quantities of water wherever it might be needed in the case of an extended fire or conflagration.

These questions were taken up with Mr. John R. Freeman, and after studies were made of different projects and of the possibilities of reservoir sites, he advised us to adopt one system for the whole city.

The single system is cheaper, simpler, and, as he thinks and as we think, it is better. This single system which is adopted means that a pressure of 130 to 140 pounds will be carried on the river bottom, and that a pressure of 70 to 80 pounds will be carried on the sand plain immediately on top of the bluff and the center of the city in the immediate neighborhood of the United States Armory, and that somewhat smaller pressures will be carried in the highest and most remote points of the city.

The site selected for the distributing reservoir is on Proven Mountain and is the only site within a corresponding distance of the city at sufficient elevation to maintain this pressure. It is very fortunate that it was possible to locate the new works so as to take advantage of this distributing reservoir site, and it was also very fortunate that a saddle was found at the right elevation in the ridge, which usually is of trap rock and too narrow and steep to afford a satisfactory site. The site selected is sufficient not only for the construction of the reservoir which is now proposed, but will also serve for an addition of another part of equal size when the growth of the city makes it desirable.

The proposed Little River works are designed all the way through with reference to extension. A 15 000 000-gallon plant is now being built, but everything is designed for an ultimate extension of double, or more than double, that capacity.

The Little River water is to be filtered, although it comes from a hilly and almost mountainous watershed that has but little population upon it. Filtering the water adds something like $300 000 to the cost of the project. It insures the delivery of a

water of greater attractiveness from a physical standpoint, and it largely eliminates possible danger of disease which might come from accidental contamination of the sources.

The filtered water is to be stored in a covered reservoir, that is to say, in the distribution reservoir on Proven Mountain. Covering this reservoir is also something of a novelty for a supply of this character. The cover is provided to keep out the light and to prevent the growth of organisms in the reservoir, which growths tend to reduce the quality of the water.

At Ludlow, as you will see on Friday when you visit the present filter, the effluent is stored in an open reservoir, called the Little Basin, which is a part of the Ludlow reservoir cut off by an embankment; and in that little basin you will see that there are growths of organisms, and the water flowing from it to the city is not of quite as good quality as the water that comes from the filters. This condition of storage of effluent in an open reservoir, with a consequent deterioration in quality, was tolerated in the Ludlow design because the whole purification plant is for temporary service, and it was, therefore, wise to take some chances on deterioration rather than spend the large additional sum required to prevent it, as we should wish to do if it was for permanent service. But in the Little River supply we propose to keep all filtered water in the dark and bring it into Springfield in just as good condition as it leaves the filters, and so attractive and wholesome that there will not be any excuse for the spring water business to exist.

Springfield started with the worst water supply of any considerable city in the state. It is the ambition of the water board and of Mr. Lochridge, and of the speaker, to carry out the works now authorized in such a way as to provide Springfield with the best water supply of any considerable city in the state.

Mr. Lochridge. Mr. President, I don't know as there is any way of describing the water when it is impregnated with Anabæna unless you have seen it, and you have got to multiply it after it is described. I will let each of you do that.

The reservoir, covering something over 400 acres, is, during the summer, filled with small, hairlike substances or filaments, which are in reality the filaments of this Anabæna. Looked at under a

microscope, they are made up of small beads, and they are each of them about two thousandths of an inch in diameter, although the filament may be half an inch long.

The water is entirely filled with this to such an extent that if you should put your hand below the surface, holding it straight below the surface, it could not be seen at all at a depth of three inches. It is frequently that way, and I haven't a doubt that some of the people who are here, that I know have lived here a good many years, could tell you they had seen it in the pipes almost as bad, but we always tell them that the water they get in the pipes is diluted, that some of it runs around the reservoir from the brook. That is one way of describing it.

Following this period, and it isn't very bad at this time,— you can drink it, it isn't very bad yet,— they begin to die and then you begin to get your tastes and odors. The oil sacs are liberated, and it was in this that one of the big problems of the filtration came.

The Anabæna in its fresh stage is handled by the filter quite easily, but when it begins to die, and you have this organic matter in this enormous quantity, in some state of decomposition, you have a form that we choose to refer to as secondary odors, and it is these secondary odors which are, to a certain extent, developed in the pipes in the passage for some 10 or 12 miles in the dark. That is the odor which it is hard to remove by filtration; in fact, the filter won't do it; it has got to be aërated following the filtration.

During 1903, when I was at the reservoir, this stage I have described lasted from the first day of August through till some time in October; that is, over two months — all of August and September. When the cold weather comes on, it coagulates; that brings it up. And the Anabæna has, in addition to the chlorophyl,— the green coloring which we know in all plants,— cyanophyl, which is a blue coloring matter. These colors separate, and the whole mass comes up and covers something like 40 or 50 acres of the reservoir. It usually gathers together in some such mass. I have seen it a number of times. That mass is from three to four inches thick, and you can put your hand in and lift out quite a good-sized cake of it. But you have got to hold it pretty carefully. It will go through rather a fine mesh. It is in

blue and green streaks. After a person visits the reservoir and looks at that, he goes home and doesn't drink the water for a year. I have had several tell me that that is exactly what they did. In reality this mass has all come out of the water before they get it in the pipes. It is not in such a bad state, but the breaking up of this matter makes a taste and odor which are decidedly objectionable, and of the worst form for the treatment by filtration and aëration.

At the time of this formation of the jelly-like mass, which always follows the period of the excessive Anabæna count, a stone the size of your fist can be rolled out upon it and it will stay there. I have seen it stay there three or four days, if you will believe it, although you are all welcome not to, as few do unless they see the reservoir during one of its very bad stages.

Mr. Weston. I should like to ask Mr. Lochridge what rate of filtration is usually employed at the Ludlow filter.

Mr. Lochridge. There are four beds of substantially an acre in extent each. We get all the water we want for each day out of that. The use of the city is between ten and twelve million gallons a day. The fact that there is no concrete bottom to the filter means that there is a considerable loss. Perhaps 40 per cent. of that loss makes its way into the basin and isn't a loss, but it doesn't go out through the underdrains. The other 60 per cent., or perhaps more, goes back into the reservoir and is not lost to the system, but is lost to the filtered water basin. And Mr. Story, who has operated the filter this year, and who is present, told me this morning that one fourth of the total amount pumped went through below the underdrains. Three beds are always operated, or practically always. I will try to have it arranged to have one bed off, so that you may see how it is cleaned on Friday when you go out to Ludlow. I don't know whether there will be mud enough on those beds or not, but you will see something about what we have done.

President Whitney. I should like to ask Mr. Hazen if this idea of filtering the new supply was the ultimate result of thinking it over, or was it intended at the start?

Mr. Hazen. I don't know as I quite get your question, Mr. President.

PRESIDENT WHITNEY. What I wanted to say was, did you at the start intend to filter this new supply, or was it something which came into the final making of the plans?

MR. HAZEN. Oh, we intended to filter it at the start.

PRESIDENT WHITNEY. Was it considered a necessity?

MR. HAZEN. No, sir; it was regarded as desirable.

MR. MURRAY FORBES. How did you arrive at the conclusion to filter instead of sanitating or purchasing some of the watershed?

MR. HAZEN. We thought we could do a lot more for the money.

PRESIDENT WHITNEY. I wonder if any of the other members present have had experience with this same organism, the Anabæna, — experiences similar to those described by Mr. Lochridge.

MR. HAZEN. I think Mr. Weston has had experience in treating such organisms.

MR. ROBERT SPURR WESTON.* Mr. President, there is not very much to be said beyond a very brief account of some experiments made for the Athol Water Department last summer. The water supply of Athol comes from two impounding reservoirs, one of which, the Phillipston reservoir, is nearly as bad as Ludlow, and is subject to growths of Anabæna, Aphanizomenon, and other organisms. The water commission authorized experiments last summer, and accordingly a small trickling filter of coarse, crushed stone and a small intermittent sand filter were built and operated with the coöperation of the Massachusetts State Board of Health. Analyses were made under the direction of the speaker. These devices were in operation from the first of September to the end of the algæ season, 1906. These devices were practically the trickling filter and the intermittent filter such as are used for sewage disposal, and were operated in a similar manner.

The water in the Phillipston reservoir is deficient in oxygen and abounds in organic matter, and it was thought that the logical remedy for the bad condition of the water would be the removal of the organisms by some method of filtration and the removal, produced by aëration or some other means, of the odor. It was also believed that on account of the deficiency of oxygen continuous filtration would not suffice. The trickling filter was operated at a rate of 2 000'000 gallons per acre per day, water

* Sanitary Expert, Boston, Mass.

being applied continuously. The intermittent sand filter was dosed three or four times a day, and the rate of filtration varied between 200 000 and 1 000 000 gallons per acre per day. The intermittent filter was operated without aëration. It was desired to obtain data for organism removal and aëration independently of one another.

After the first week the effluent from the intermittent filter was nearly colorless and free from turbidity. It had a musty odor, however, but it must be remembered that this filter was purposely operated without aëration.

The effluent from the trickling filter as it came was almost completely free from odor, but it was not free from organisms. Consequently, after a short time, the aërated water again possessed an objectionable odor. Briefly stated, the experiments proved that a thorough aëration would remove the odor from the water and that intermittent filtration would remove most of the color and all the turbidity. The results of operation are as follows:

REMOVAL OF ORGANISMS.

Source.	Average Number of Organisms per c. c.	Percentage Removed.
Phillipston Reservoir	5 637	0
Filter No. 1	2	99.96
Filter No. 2	3 996	30

The almost complete removal of the organisms by Filter No. 1 is noteworthy.

Removal of Odor. The trickling filter No. 2 removed 45 per cent. of the odor, as shown after the samples had been received in the laboratory. Filter No. 1 removed only 10 per cent.

REMOVAL OF COLOR.

Source.	Average Color.	Percentage Removed.
Phillipston Reservoir	0.60	0
Filter No. 1	0.06	90
Filter No. 2	0.54	10

REMOVAL OF ORGANIC MATTER AS SHOWN BY NITROGEN AS FREE AMMONIA. PARTS PER 100 000.

Source.	Average Free Ammonia.	Percentage Removed.
Phillipston Reservoir	0.0100	0
Filter No. 1	0.0021	79
Filter No. 2	0.0131	—31 (apparent increase)

REMOVAL OF ORGANIC MATTER AS SHOWN BY THE TOTAL NITROGEN AS ALBUMINOID AMMONIA. PARTS PER 100 000.

Source.	Average Albuminoid Ammonia.	Percentage Removed.
Phillipston Reservoir	0.0673	0
Filter No. 1	0.0136	80
Filter No. 2	0.0587	13

The logical conclusion from these experiments was that the organisms, and to a great extent their food material, could be removed by intermittent filtration, but that filtration without aëration did not suffice. The experiments also showed that the rate at which the intermittent filter operated, less than 1 000 000 gallons per acre per day, could be increased considerably and still furnish an agreeable effluent.

MR. ROBERT J. THOMAS.* Mr. President, Mr. Lochridge says that one filtration or two filtrations and aëration will not remove the Anabæna, or the trouble from the Anabæna. I would like to ask his opinion of spreading that out on such sand or gravel on a natural slope, perhaps 30 or 40 feet above, and falling into it, three, four, or five hundred feet away from the filtration gallery or collecting gallery; let it filter through this natural sand or gravel into this gallery. Would that remove it, do you think?

MR. LOCHRIDGE. I wouldn't be able to say. We get an immense amount of material, of muck or mud or whatever it is, on top of the sand. If you had sand of just the right kind and made a gravel filter, I should think it would. But we find that our sand very soon becomes used up, covered up, and there is no question but what its life would be short were it not possible to take off the Anabæna which is taken out. And, in fact, every four to ten days during the season, according to the amount of Anabæna and other conditions of the water, it is necessary to take off a layer of the sand, which is practically watertight.

MR. THOMAS. Mr. President, in removing the Anabæna, if I understand, he didn't get satisfactory results with the two filtrations and the aëration.

MR. LOCHRIDGE. That was true in the 1903 experiments which were made; yes, sir.

* Superintendent of Water Works, Lowell, Mass.

Mr. Thomas. Not all of it was removed; some remained in the water?

Mr. Lochridge. Only at the time of the worst water.

Mr. Weston. Mr. President, if I might take the liberty of replying to Mr. Thomas's question, I would say that the essential thing in a filter for the removal of the excessive odor due to organisms is to periodically drain the sand layer and give it fresh air. There is not enough dissolved oxygen in water of the class treated to burn up the large amounts of organic matter which are being stored in the filter day after day. Consequently, the water must receive a treatment more like that given sewage where one doses the filter and then gives it a day's rest in order that the bacteria which effect the destruction of the organic matter may be revivified by the aëration of the bed; it is well known to all that the bacteria which effect the destruction of organic matter, whether in sewage or water, not only live upon the organic matter, but require oxygen as well.

I would like, Mr. President, to ask if the copper sulphate treatment has been considered in Springfield. I would like to ask Mr. Hazen if he has considered it in other cases similar to those outside of Massachusetts.

Mr. Hazen. I suggested the use of copper sulphate, or at least endorsed its use for the Ludlow water, but the state board of health was against us on that point, and as we had to have their coöperation and support in other matters, that matter was not pressed. In other cases I have approved of the use of copper sulphate, where Anabæna has been troublesome, and from it considerable relief has been experienced; but in no case has good clean water been secured by this treatment of the water, corresponding to that which can be obtained by proper filtration and aëration.

Mr. M. F. Collins.* Mr. President, I should like to ask Mr. Lochridge what effect the size of the sand has on the contents of the filter.

Mr. Lochridge. The sand was analyzed and put in by analysis. That is, one or two men spent their whole time watching the sand bed as it went in. We tried to get sand of 0.35 of a milli-

* Superintendent of Water Works, Lawrence, Mass.

meter. We did get that size for a considerable part of it. I think, however, that while we could get as high as 0.44 at times, or a little higher, that a statement of size of between 0.30 and 0.35 would be about right for all of it, considering the way it was mixed.

President Whitney. I should like to ask Mr. Lochridge how uniform that sand runs.

Mr. Lochridge. No uniformity at all; that is, it went in as it was found. The larger stones were eliminated where we could and put in a bucket. If we picked up about a yard, and got but few in it, we let them stay. We raked them off from the top,— that is practically all, — and made a uniform height.

Mr. Codd. I should like to ask Mr. Lochridge if the filters handle the Uroglena as effectually as the Anabæna.

Mr. Lochridge. They certainly do some pretty good work on it. I think we had something like 30 000 per cubic centimeter for a while. I don't know how it would hold out for a long period, but we certainly got very good water. It does not handle it as easily; the filters clog up much quicker. Possibly it would require larger filters, and probably it would require greater aëration, but it did handle the water that we had.

President Whitney. We should like to hear from Mr. George A. Johnson on this subject.

Mr. George A. Johnson.* Filtration problems which have to do with the removal of tastes and odors from water are never very easy of solution. Here at Springfield, however, the promises are strong that this most disagreeable and vexatious phase of the question is being successfully overcome, and the manner in which this is being brought about reflects great credit upon the engineer of the department and his advisers.

In his travels of last year one of the most striking examples of the difficulties to be encountered by water-works men in tropical countries came to the speaker's attention in going over the situation at Singapore, Straits Settlements. Here the supply is derived from small jungle streams draining about 25 square miles of area, much of which is swampy in nature. The water is highly colored as received at the storage reservoir and frequently possesses a strong fishy odor, and the taste is often highly objec-

* Principal Assistant Engineer with Hering & Fuller, New York City.

tionable. The storage reservoir has a capacity of about 1 000 000-000 gallons, corresponding roughly to a storage of 200 days. This long period of storage apparently does not affect the character of the water to any material extent, and on walking around and closely examining the banks of this reservoir, the speaker was unable to detect any signs of algal growth.

The water is filtered before consumption through slow sand filters which, when operated in the usual manner, were not successful in effecting a diminution in the objectionable tastes and odors. In view of this fact the municipal engineer adopted a scheme of operation whereby the beds were allowed to rest empty for a period of about twelve hours in every one or two weeks, maintaining a rate of filtration when in operation of about 1 000 000 gallons per acre daily. According to statements made by those in charge of the works and citizens of Singapore, this intermittent method of operation has proved successful in this case in the more satisfactory treatment of the Singapore water. At the time of the speaker's visit, however, although this method of operation was then in use, the filtered water possessed a strong odor and was quite objectionable to the taste.

With reference to rainfall statistics, some interesting data were found at Calcutta, where, although the annual rainfall amounts to only about 60 inches, as much as 40 inches has fallen in a single week, and quite recent records show that there have been daily rainfalls amounting to as much as 10 to 15 inches.

Few people realize the stupendous progress which is being made by the Japanese in water filtration matters. Although the first public water supply was inaugurated at Tokyo in the year 1600, it was not until 1885 that the first modern system of water-works, including slow sand filters, was put under construction at Yokohama.

At the present time there are 13 cities in Japan, with an aggregate population of 4 000 000, which are supplied with filtered water. In considering the comparative populations of Japan and America, it is seen that Japan practically stands on a par with America so far as her progress in this line of municipal sanitary work is concerned.

The piping systems are quite complete and about one third of

all the service lines are metered. There is a fire hydrant to about every 50 houses. The total cost of all Japanese water works to date is about $11 500 000, or $115 000 per million gallons, or $2.80 per capita.

Very little water is wasted in Japan, as shown by the fact that the average water consumption amounts to no more than 25 gallons per capita per day.

President Whitney. I wonder if Mr. Codd would give us his experience with filters.

Mr. Wm. F. Codd.* Well, I don't know that I can say much about it. We have the Anabæna occasionally, but we haven't done anything with it except avoid it by getting ground water. We haven't been able to filter it successfully. At times it shows very thick in the pond; looks as though one had put valvoline oil into the water. It has about that dark-green appearance. I don't think I can tell you anything about filtering it.

President Whitney. I imagine that very few departments are so situated that they can avoid trouble as Mr. Codd does, by using the ground water. We would like to hear the views of Mr. Story, the operator of the filter in Springfield — your views in a general way, Mr. Story, in regard to the operation of the plant.

Mr. C. F. Story.† Mr. President, I don't know that I can add anything to what Mr. Lochridge has said, but I would be very glad to answer any questions along the line of operation and methods. I think perhaps I can tell the members more when they make the trip on Friday.

Mr. Hazen. Tell them about the dissolved oxygen in the effluent.

Mr. Story. I make the practice of taking my samples of dissolved oxygen directly from the small underdrains, so as to get a sample of the water after it has passed through the bed and before it has had any aëration. On a bed that is clean and running at a good rate the dissolved oxygen is always high, and as the bed grows dirtier it drops. In the worst periods of the reservoir water the dissolved oxygen dropped to a point as low as 35 per cent. saturation. At such times the filter gave an effluent which was

* Superintendent of Water Works, Nantucket, Mass.
† Assistant Engineer, Springfield Water Works.

as high as 80 per cent. saturation. I always watch the underdrains closely, and it is my endeavor to shut off a bed, if possible, when the dissolved oxygen in the effluent has dropped to a point less than 70 per cent. saturation. When we find the dissolved oxygen is being reduced in the filtered water, we remove the water from the filter, scrape the bed, and clean it out. In that way the water is always good.

MR. COLLINS. I should like to ask Mr. Story a question. I understand that the operation of this is about sixteen hours a day. I want to know what his rate of filtration is to aërate the sand.

MR. STORY. I wouldn't want to say off-hand, but figuring on the sixteen hours a day, it would be considerably over 3 000 000.

PROF. LEONARD P. KINNICUTT.* What limit do you set to dissolved oxygen before you change the filter, — before taking it off?

MR. STORY. I think I can best express that by saying that we started in June at the reservoir with the dissolved oxygen 90 per cent. saturation, and it ran down during the worst periods to as low as 35 per cent. saturation. The filters when working well always give between 75 and 90 per cent., and I usually took the filter off when it dropped below 70 per cent. saturation.

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*Worcester Polytechnic Institute, Worcester, Mass.

PROCEEDINGS.

JUNE 26, 1907.

The annual "field day" of the Association was devoted to an excursion to Gloucester, Mass., by steamer *Cape Ann;* a shore dinner, followed by a trolley ride around Cape Ann; and a return to Boston by train.

No business meeting of the Association was held.

TWENTY-SIXTH ANNUAL CONVENTION, SPRINGFIELD, MASS., SEPTEMBER 11, 12, AND 13, 1907.

The twenty-sixth annual convention of the New England Water Works Association was held at Springfield, Mass., on Wednesday, Thursday, and Friday, September 11, 12, and 13, 1907, at the Cooley Hotel.

The following members and guests were in attendance:

HONORARY MEMBERS.

F. W. Shepperd. — 1.

MEMBERS.

S. A. Agnew, Kenneth Allen, J. M. Anderson, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, H. K. Barrows, G. W. Batchelder, W. U. C. Baton, J. E. Beals, J. F. Bigelow, F. E. Bisbee, G. H. Bishop, J. W. Blackmer, E. M. Blake, C. A. Bogardus, James Burnie, C. H. Campbell, L. G. Carleton, T. J. Carmody, J. C. Chase, J. H. Child, H. W. Clark, W. F. Codd, M. F. Collins, W. R. Conard, J. H. Cook, P. C. Denehy, John Doyle, M. J. Doyle, E. D. Eldredge, E. A. Ellsworth, L. N. Farnum, J. A. Fitch, A. A. Fobes, A. P. Folwell, A. B. Farnham, Murray Forbes, E. H. Foster, A. N. French, F. L. Fuller, S. DeM. Gage, F. J. Gifford, D. H. Gilderson, A. S. Glover, X. H. Goodnough, E. L. Grimes, P. T. W. Hale, R. A. Hale, F. E. Hall, J. C. Hammond, Jr., J. D. Hardy, A. R. Hathaway, W. C. Hawley, N. W. Hayden, Allen Hazen, A. B. Hill, G. A. Johnson, W. E. Johnson, Willard Kent, A. C. King, G. A. King, H. M. King, L. P. Kinnicutt, J. J. Kirkpatrick, E. E. Lochridge, F. H. Luce, S. H. McKenzie, T. H. McKenzie, Hugh McLean, H. B. Machen, C. T. Main, A. E. Martin, D. H. Maury, John Mayo, A. S. Merrill, F. E. Merrill, Leonard Metcalf, H. A. Miller, F. F. Moore, T. W. Norcross, O. A. Parks, Washington Paulison, E. M. Peck, E. L. Peene, E. B. Phelps, A. E. Pickup, A. A. Reimer, W. H.

Richards, H. W. Sanderson, Charles Saville, E. M. Shedd, C. W. Sherman, M. A. Sinclair, H. O. Smith, P. S. Smith, H. T. Sparks, J. F. Sprenkel, G. A. Stacy, W. H. Sutherland, C. F. Story, W. F. Sullivan, R. J. Thomas, W. H. Thomas, J. L. Tighe, J. A. Tilden, D. N. Tower, C. A. Townsend, W. H. Vaughn, J. H. Walsh, C. S. Warde, R. S. Weston, J. C. Whitney, C.-E. A. Winslow, G. E. Winslow, I. S. Wood, Walter Wood, C. L. Wooding, L. C. Wright. — 119.

ASSOCIATES.

Anderson Coupling Company, by Charles E. Pratt; Roy S. Barker; Harold L. Bond Company, by F. M. Bates; Builders Iron Foundry, by A. C. Coulters; Central Foundry Company, by C. F. Blunt; Chapman Valve Manufacturing Company, by Edward F. Hughes, R. W. Wight, W. V. Threlfall, and Edward L. Ross; The Fairbanks Company, by F. A. Leavitt and C. A. Sleeper; Hart Packing Company, by Horace Hart; Hays Manufacturing Company, by T. F. Nagle; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey, and William C. Sherwood; International Steam Pump Company, by Samuel Harrison and J. W. Sims; Monarch Valve Manufacturing Company, by W. D. Hosley; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by A. C. Pilcher and G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by C. A. Vaughan, F. A. Smith, and H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford and W. G. Ryan; Pitometer Company, by E. M. Blake; Pittsburg Meter Company, by T. C. Clifford and V. E. Arnold; Platt Iron Works Company, by T. H. Hayes; Rensselaer Manufacturing Company, by Fred S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; A. P. Smith Manufacturing Company, by F. N. Whitcomb and Anthony P. Smith; Thomson Meter Company, by E. M. Shedd, S. D. Higley, and W. S. Cetti; Union Meter Company, by L. P. Anderson, F. E. Hall, and C. F. Merrill; United Lead Company, by Frederick H. Craig; United States Cast Iron Pipe & Foundry Company, by Thomas H. McGechin and F. W. Nevins; Water Works Equipment Company, by W. H. Van Winkle and W. H. Van Winkle, Jr.; R. D. Wood & Co., by Charles R. Wood and Walter Wood.— 53.

GUESTS.

J. F. Beladeau, H. H. Hawkesworth, Pittsfield, Mass.; F. P. Martin, L. F. Ivers, West Springfield, Mass.; A. A. Adams, F. W. Dickinson, Edwin G. Rude, F. A. Holden, J. J. Fitzgerald, Mr. and Mrs. E. S. Green, Charles Davis, J. K. Barker, Mrs. H. P. Small, H. C. Emerson, George F. Merrill, H. T. Murphy, M. L. Miller, and E. T. Kavanaugh, Springfield, Mass.; L. B. Cummings, F. S. Dewey, Jr., and Chas. N. Oakes, Westfield, Mass.; W. A. Brown, Greenfield, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. Irving S. Wood, Providence, R. I.; P. J. Lucey, F. J. Millane, A. F. Sickman, Robert E. Newcomb, Patrick Gear, James F. Cleary, Miss Alice S. Corner, and Miss K. G. Sullivan, Mrs. E. A. Ellsworth, Holyoke, Mass.; Mrs. H. O. Smith, Leicester,

Mass.; T. A. Collins, Lawrence, Mass.; Mrs. D. H. Gilderson, Haverhill, Mass.; Mrs. Wm. H. Thomas, Hingham, Mass.; Mrs. D. N. Tower, Cohasset, Mass.; Mrs. L. M. Bancroft, Reading, Mass.; Mrs. W. H. Vaughn, Wellesley, Mass.; Mrs. George A. King, Miss King, Taunton, Mass.; Mrs. Murray Forbes, Greensburg, Pa.; Mr. H. P. Keegan, Cleveland, Ohio; Mr. R. Winthrop Pratt, Columbus, Ohio; Roscius C. Newell, Three Rivers, Mass.; James G. Hill, Lowell, Mass.; F. N. Carpenter, Northfield, Vt.; Bertram Brewer, Waltham, Mass.; F. S. Robinson, Waterford, N. Y.; George R. Taylor, Scranton, Pa.; W. H. Jackson, Providence, R. I.; Mrs. John Mayo, Bridgewater, Mass.; H. R. Cooper, Thompsonville, Conn.; Mrs. F. H. Luce, George C. Dickel, Woodhaven, N. Y.; C. A. Goodhue, Thompsonville, Conn.; A. E. Blackmer, Plymouth, Mass.; Joseph M. Brown, East Orange, N. J.; Mrs. W. H. Van Winkle, Thaddeus Newman, G. E. Sly, Frank C. Wright, A. E. Kornfeld, New York City; W. W. Bryan, Paterson, N. J.; Mrs. Ena B. Small, Portland, Me.; Mrs. Edward L. Peene, Yonkers, N. Y.; H. B. Morton, Bristol, Conn.; Edwin Leavitt, Somerville, Mass.; Mrs. E. M. Shedd, West Somerville, Mass.; John J. Barry, Chicopee, Mass.; Mrs. Frank L. Fuller, Harry S. Brown, F. C. Putney, P. H. Gallaher, J. R. Fletcher, T. P. Taylor, E. A. Stevens, Mrs. H. H. Kinsey, Miss Joan M. Ham. — 81.

[Names counted twice — 7.]

The convention was called to order at 12 M., on Wednesday, September 11, in the convention room at the Cooley Hotel, with President John C. Whitney in the chair.

President Whitney. I have to announce the opening of the Twenty-Sixth Annual Convention of the New England Water Works Association. We meet this year in a city which has faced and is facing difficult municipal problems in a broad-minded, businesslike way, and I take great pleasure in introducing the Hon. William E. Sanderson, Mayor of the city of Springfield.

Mayor Sanderson. *Mr. President, Ladies, and Members of the New England Water Works Association:* It is not my purpose to occupy your time to any extent with remarks of mine, knowing full well that you are here to consider problems which apply to your particular line of business. It is very true that Springfield is confronting problems of great magnitude, and particularly in your line lies one of them. The details of that problem will be presented to you very ably by the engineers of our Water Department.

I cannot help but appreciate — and the people appreciate — these gatherings, where there is an exchange of ideas on the problems confronted in the different localities from which you have the honor to come. It is the exchanging of those ideas which

makes it possible for us to attain the highest degree of efficiency and perfection in these problems which affect the people of our respective communities.

Gentlemen, it affords me great pleasure, on behalf of the city of Springfield, to extend to each and every one of you a most cordial greeting and hearty welcome. We trust that your stay in our city may be most pleasant and profitable to you, and that you may carry away with you pleasant memories of the city of Springfield.

Gentlemen, I thank you.

PRESIDENT WHITNEY. The Secretary has some applications for membership which have been passed upon by the Executive Committee, and which he will read. Mr. Secretary, will you read the applications that you have?

SECRETARY KENT. I have applications for membership from: Henry B. Lake, chemical engineer, Canadian Pacific Railway, Winnipeg, Manitoba; Edward Sutherland Stokes, medical officer and biologist to Metropolitan Board of Water Supply and Sewerage, Sydney, N. S. W., Australia; Arthur C. King, assistant engineer, Increased Water Supply, Springfield, Mass.; Cassius E. Gillette, recently chief engineer, Bureau of Filtration, Philadelphia, Pa.; William McCarthy, superintendent, Bluefield Water Works and Improvement Company, Bluefield, W. Va.; Harrie L. Davenport, water commissioner, South Framingham, Mass.; Carroll F. Story, assistant engineer, Springfield Water Department, Ludlow, Mass.; Henry Richards, trustee, Gardiner Water District, Gardiner, Me.; Frank L. Clapp, superintendent of Water Works, Stoughton, Mass.; and for Associate Membership, from United Lead Company, New York, N. Y.

These applications are all properly endorsed, and have been recommended by your Executive Committee.

PRESIDENT WHITNEY. You have heard the applications. What is your pleasure?

MR. L. M. BANCROFT. Mr. President, I move that the Secretary be authorized to cast one ballot for the election of the applicants named.

Motion seconded and carried. The Secretary thereupon cast a ballot, and the President declared the applicants duly elected.

Mr. R. J. Thomas. Mr. President, I move that the thanks of the Association be extended to his Honor the Mayor for meeting with us to-day.

Motion seconded and carried.

Meeting adjourned.

Afternoon Session, Wednesday, September 11, 1907.

President John C. Whitney in the chair.

President Whitney. The Secretary has some applications for membership which he will read.

Secretary Kent. We have applications from: J. H. Child, superintendent of water works, Wallingford, Conn.; Arthur B. Farnham, city engineer, Pittsfield, Mass.; H. O. Lacount, engineer and assistant secretary, Inspection Department, Associated Factory Mutual Insurance Companies, Boston, Mass.; R. R. Newman, civil engineer with William Wheeler, Boston, Mass.; W. G. Dryden, superintendent, Montreal Water and Power Company, Montreal, Canada; William H. Sutherland, assistant engineer, Montreal Water and Power Company, Montreal, Canada; Lawrence C. Brink, New Paltz, New York; P. F. Carmody, water commissioner, Holyoke, Mass.; and for Associate Membership, Monarch Valve and Manufacturing Company, Springfield, Mass.

These are all properly endorsed and recommended by your Executive Committee.

President Whitney. You have heard the list of applications. What action will you take?

Mr. Collins. Mr. President, I move that the Secretary cast one ballot and that they be declared elected.

Motion seconded and carried. The Secretary then cast a ballot, and the President declared the applicants elected.

Mr. Charles W. Sherman. Mr. President, the constitution requires that at some time during the convention a nominating committee be elected or appointed, to name officers for the ensuing year. In accordance with the usual custom, I offer a motion that the President appoint a nominating committee of five.

President Whitney. You have heard Mr. Sherman's motion. Is it seconded?

Motion seconded.

PRESIDENT WHITNEY. It is moved and seconded that the President be authorized to appoint a committee of five to bring in a list of officers for the ensuing year. All those in favor say Aye.

VOICES. Aye.

PRESIDENT WHITNEY. Contrary minded, No. It is a vote.

Mr. Elbert E. Lochridge, chief engineer, Springfield Water Works, then presented a description of the Springfield Water Works, illustrated by stereopticon. The paper was discussed by Messrs. Allen Hazen, Robert Spurr Weston, Murray Forbes, C. F. Story, M. F. Collins, R. J. Thomas, Wm. F. Codd, George A. Johnson, and L. P. Kinnicutt.

Meeting adjourned.

EVENING SESSION, WEDNESDAY, SEPTEMBER 11, 1907.

Mr. Allen Hazen gave a talk on his recent visit to Australia, illustrated with lantern slides of water works and other views of interest.

The next paper was "Description of Plant at Peabody, Mass., involving Construction of Tunnel, New Reservoir, New Pumping Station, and High Duty Worthington Pump," by F. A. Barbour, C. E., Boston, Mass.

Adjourned.

MORNING SESSION, THURSDAY, SEPTEMBER 12, 1907.

President Whitney in the chair, at the opening; later, Vice-President George A. King.

This session was devoted to the general subject of damages resulting from diversion of water. Mr. Charles T. Main, of Boston, read a paper entitled "Computation of the Value of Water Power, and the Damages caused by the Diversion of Water used for Power." Mr. Richard A. Hale, of Lawrence, Mass., followed with a paper on the subject of "Water Rights." A paper entitled "Damages Caused by the Diversion of Water Power," by Mr. Clemens Herschel, of New York, was presented by title, in the absence of the writer.

The discussion was taken up on these three papers jointly, and the following gentlemen took part: Messrs. H. K. Barrows, Leonard Metcalf, W. C. Hawley, Kenneth Allen, Charles T. Main,

George A. King, Richard A. Hale, Charles W. Sherman, J. H. Cook, E. L. Grimes, E. H. Foster, and A. A. Reimer. Mr. E. H. Foster offered the following motion:

"That a committee be appointed by the chair to approach the National Cotton Manufacturers' Association and invite them to appoint a committee, these committees to act as a joint committee to draw up a set of rules to govern the estimation of damage to water privileges by diversion."

Seconded.

Mr. Charles W. Sherman offered the following as a substitute motion:

"That a committee of five be appointed by the President to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers' Association, or other organizations of mill owners, leading to the formulation of standard rules and methods of computing or assessing damages for the diversion of water."

The substitute motion was accepted by Mr. Foster, and, a vote being taken, it was adopted. (The President subsequently appointed as members of this committee, Messrs. Charles T. Main, Leonard Metcalf, R. A. Hale, Charles E. Chandler, and William Wheeler.)

The Chairman made the following announcement:

The South Norwalk, Conn., sand filters are being constructed for the purification of the public water supply. These filters present some novel features, and should be of considerable interest to members of this Association. The South Norwalk Water Commissioners would be glad to have as many members of the Association as possible visit their plant on Saturday next, and will furnish transportation by automobiles from the South Norwalk station to the filters, a distance of about nine miles, and provide a lunch. If any members of the Association desire to accept this invitation please give their names to the Secretary or Mr. H. W. Clark.

Adjourned.

AFTERNOON SESSION, THURSDAY, SEPTEMBER 12.

President Whitney presided.

Mr. Bertram Brewer, city engineer of Waltham, Mass., read a paper on "The Waltham Reinforced Concrete Reservoir," illustrated by stereopticon. The paper was discussed by Messrs. T. H. McKenzie, Leonard Metcalf, H. K. Barrows, Kenneth Allen, Dabney H. Maury, W. C. Hawley, Allen Hazen, Walter H. Richards, A. A. Reimer, A. Prescott Folwell, Frank L. Fuller, and Mr. Brewer.

Mr. William R. Conard then read a paper entitled, "Cast-Iron Pipe Specifications." It was discussed by Messrs. T. H. McKenzie, W. H. Richards, Walter Wood, A. A. Reimer, Frank L. Fuller, and the author.

Adjourned.

EVENING SESSION, THURSDAY, SEPTEMBER 12.

Mr. Hiram A. Miller gave an illustrated talk on "The Charles River Basin."

The Secretary read applications for membership from the following persons:

J. D. Walker, Belfast, Me..; John J. Kirkpatrick, superintendent, Holyoke Water Works, Holyoke, Mass.; Frank J. Gifford, general foreman, Fall River Water Works, Fall River, Mass.; Chester R. McFarland, superintendent of Water Works, Tampa, Fla.,

all of which had been approved by the Executive Committee.

On motion, the Secretary was authorized to cast the favorable vote of the Association for the applicants, which he did, and they were declared elected.

The President announced his appointments to the committees previously authorized as follows:

Nominating Committee. — Dexter Brackett, Alfred D. Flinn, Robert C. P. Coggshall, Edwin C. Brooks, Frederick W. Gow.

Committee on Water Damages. — Charles T. Main, Leonard Metcalf, R. A. Hale, Charles E. Chandler, and William Wheeler.

PRESIDENT WHITNEY. The Association received an invitation from the Water Commission of South Norwalk to visit their filter plant on Saturday of this week. The invitation was received through Mr. H. W. Clark, but so few members have evinced a

disposition to make the excursion that it will have to be abandoned. Now, in reference to the excursion to-morrow, special trolley cars will leave the front of this hotel at nine o'clock sharp. That means the cars will leave at that time. Members must be on the sidewalk at least five minutes previous to that time.

Mr. E. M. Blake described briefly a new pitometer recording outfit for use in determining the slip of pumps.

Convention adjourned.

Friday, September 13, 1907.

In the forenoon the Association was taken by special electric cars to the works of the Chapman Valve Manufacturing Company, at Indian Orchard, and was entertained by that company. The manufacturing plant was of much interest, and so also was the excellent luncheon that followed. A vote of thanks to the Chapman Valve Manufacturing Company was proposed by Mr. R. J. Thomas, and was carried unanimously.

In the afternoon many of the members visited the Ludlow filters of the Springfield Water Works and others took advantage of the opportunity to visit the Springfield armory.

Report of Committee on Exhibits.

Mr. J. C. Whitney, President,

New England Water Works Association:

Dear Sir, — I hereby submit report of Committee on Exhibits at annual meeting held at Springfield, Mass., September 11–13.

The exhibitors were as follows:

National Meter Company	Meters.
Neptune Meter Company	Meters.
Pittsburg Meter Company	Meters.
A. P. Smith Manufacturing Company,	Photographs and samples of work.
Hersey Manufacturing Company . . .	Meters.
Thomson Meter Company	Meters.
International Steam Pump Company,	Worthington Meters.
Ross Valve Manufacturing Company .	Hydraulic blowing engine and pressure regulating devices.
The Fairbanks Company	Valves and hydrants.
Hays Manufacturing Company . . .	Shut-offs, lead connections and patent lead-pipe joints.

H. Mueller Manufacturing Company . .	Shut-offs, tapping machine, and general water-works tools.
Monarch Valve Manufacturing Company,	Valves.
United Lead Company	Lead wool.
Union Water Meter Company	Meters and pressure regulators.
Hart Packing Company	Fibrous packing, steam and water.
Anderson Coupling Company	Patent lead pipe joints.
Lead Lined Iron Pipe Company . . .	Lead and tin-lined pipe and fittings.
The Pitometer Company	Pitometer.
Water Works Equipment Company .	Photos of tapping machines.
Central Foundry Company	Cast-iron pipe.
Fire and Water Publishing Company.	

Twenty-one associate members availed themselves of the opportunities offered to exhibit.

Space occupied by exhibits, 400 square feet.

Respectfully submitted,

EDWARD F. HUGHES, *Committee.*

EXECUTIVE COMMITTEE.

WEDNESDAY, June 26, 1907, 11.30 A.M.

Meeting of the Executive Committee of the New England Water Works Association, on steamer *Cape Ann, en route*, Boston to Gloucester.

Present: President Whitney, and members, Charles W. Sherman, D. N. Tower, Robert J. Thomas, L. M. Bancroft, George W. Batchelder, George A. King, and Willard Kent.

The following applications were received and recommended for active membership, viz.:

Henry B. Lake, Edmund Sutherland Stokes, Arthur C. King, Cassius E. Gillette, William McCarthy, Harrie L. Davenport, Carroll F. Story, Henry Richards, Frank L. Clapp.

Voted: That the next annual convention of this Association be held at Springfield, Mass., and that the Secretary be a committee to make the necessary arrangements therefor.

Adjourned.

Attest: WILLARD KENT, *Secretary*.

BOSTON, MASS.,
August 20, 1907.

Meeting of the Executive Committee of the New England Water Works Association at Tremont Temple, pursuant to call issued by the Secretary at the request of the President.

Present: President John C. Whitney, and members, Charles W. Sherman, George A. King, A. E. Martin, Lewis M. Bancroft, Robert J. Thomas, and Willard Kent.

The President appointed Mr. Edward F. Hughes of the Chapman Valve Manufacturing Company, 94 Pearl Street, Boston, Mass., a committee in charge of exhibits of Associates for the September convention of 1907.

A communication from the Chapman Valve Manufacturing Company, inviting the Association to inspect their works and

partake of lunch was received and accepted for Friday, September 13.

Adjourned.

Attest: Willard Kent, *Secretary.*

Springfield, Mass.,
Wednesday, September 11, 1907.

A meeting of the Executive Committee of the New England Water Works Association was held at the Cooley Hotel at 2.30 P.M.

Present: President John C. Whitney, and members, George A. King, A. E. Martin, D. N. Tower, George W. Batchelder, Lewis M. Bancroft, Charles W. Sherman, Robert J. Thomas, and Willard Kent.

The following applications were received and recommended for membership:

J. H. Child, superintendent, Wallingford, Conn.; Arthur B. Farnham, city engineer, Pittsfield, Mass.; H. O. Lacount, engineer and assistant secretary, Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.; R. R. Newman, civil engineer with William Wheeler, Boston, Mass.; John J. Kirkpatrick, superintendent, Holyoke Water Department, Holyoke, Mass.; W. G. Dryden, superintendent, Montreal Water and Power Company, Montreal, Canada; Wm. H. Sutherland, assistant engineer, Montreal Water and Power Company, Montreal, Canada; Lawrence C. Brink, New Paltz, N. Y.; Monarch Valve and Manufacturing Company, Valve Manufacturers, Springfield, Mass.; United Lead Company, Manufacturers, Lead Wool, New York City; Frank J. Gifford, general foreman, Fall River, Mass.; P. J. Carmody, water commissioner, Holyoke, Mass.; J. D. Walker, Belfast, Me.; Chester R. McFarland, superintendent, Water Works, Tampa, Fla.

Adjourned.

Attest: Willard Kent, *Secretary.*

OBITUARY.

Louis P. Collins, ex-mayor of Lawrence, Mass., died at his home in Manchester, N. H., on October 1, 1907, after a lingering illness. He had removed there from Lawrence three years ago. He was treasurer and manager of the Derryfield Lumber Company.

He was born in Sheffield, Ontario, in 1851. He located in Lawrence when a boy, going to work in a sash and blind shop. He gradually advanced until he became treasurer and manager of the Briggs & Allen Company, of that city.

In 1888 he entered politics, and was that year chosen a member of the Lawrence city council. The following year he was elected alderman, and in 1890 was elected mayor.

He joined the New England Water Works Association on December 12, 1894.

BOOK REVIEWS.

CLEAN WATER AND HOW TO GET IT. By Allen Hazen. New York: John Wiley & Sons. 1907. 5½ x 8 inches. vi + 178 pp. With 14 half-tone plates. Price, $1.50.

Mr. Hazen says in his preface, "Its object is to help beginners to understand something of first principles. Members of water boards and water works superintendents have largely passed this stage, and it is therefore not for them."

While this may have been the author's idea in preparing the book, and while most water-works engineers, superintendents, and experienced members of water boards have, no doubt, more or less clear ideas on most of the subjects referred to, very few of them, it is safe to say, have so complete information upon these subjects that they will not learn much that will prove valuable, as well as interesting, from this little book.

The titles of the chapters are: Impounding Reservoir Supplies; Water Supplies from Small Lakes; Supplies from the Great Lakes; Water Supplies from Rivers; Ground Water Supplies; On the Action of Water on Iron Pipes and the Effect thereof on the Quality of the Water; Development of Water Purification in America; On the Nature of the Methods of Purifying Water; On the Application of the Methods of Water Purification, arranged according to the Matters to be removed by the Treatment; Storage of Filtered Water; On the Required Sizes of Filters and Other Parts of Water Works; As to the Pressure under which Water is to be delivered; On the Use and Measurement of Water; Some Financial Aspects; The Laying Out and Construction of Works; On the Financial Management of Publicly Owned Water Works.

To one who knows of Mr. Hazen's broad experience in these lines and the clearness with which he writes, it is hardly necessary to say more; to others, no better advice can be given than to get the book and see for themselves.

ICE FORMATION, WITH SPECIAL REFERENCE TO ANCHOR ICE AND FRAZIL. By Howard T. Barnes, Associate Professor of Physics, McGill University. New York: John Wiley & Sons. 1906. 6 x 9 inches. 257 pp., 40 figs. $3.00.

This book should prove very valuable to those who have to do with the operation of water-works intakes or water-power plants in the northern part of the country, where stoppages from ice are not infrequent, or are avoided only by great care and constant vigilance while the temperature remains below the freezing point.

The St. Lawrence River at Montreal has perhaps given more trouble in this way than any other stream, not only on account of the considerable use for

power, but also because the obstruction caused by ice in the river at the foot of the Lachine Rapids has caused many destructive floods in Montreal. This has caused the problem to be studied there with particular thoroughness, and Professor Barnes has utilized the results of the studies in this book.

Considerable space is devoted to the physical laws relating to the transmission of heat and the formation of ice; to temperature measurements, and to the theories accounting for frazil and anchor ice; and, finally, there is a chapter on methods of overcoming the ice problem in engineering work. To the engineer, this chapter is the most important, and it is to be regretted that it constitutes but 23 pages, or less than 10 per cent. of the book.

THE ANALYSIS AND SOFTENING OF BOILER FEED WATER. By Edmund Wehrenfennig and Fritz Wehrenfennig (Austria). Translated by D. W. Patterson. New York: John Wiley & Sons. 1906. 6 x 9 inches. xiv + 290 pp., 171 figs. $4.00.

This book deals with a problem with which New England water users, fortunately, have little to do, since the waters of this section are generally soft. In the greater part of the country, however, the natural waters, whether derived from streams, lakes, or underground sources, are hard, and their use in steam boilers results in the formation of much scale, except where great precautions are taken. With some waters the use of a suitable boiler compound and a comparatively frequent washing out of the boiler serve to prevent the formation of scale; others, however, can only be rendered fit for boiler use by a chemical softening process.

In this country water softening has been most frequently resorted to by the railroads and by industrial corporations requiring softer water for boiler feeding than could be obtained except by treatment; but there are a few municipal water supplies which are softened, and it is probably safe to predict that a much larger number of public water supplies will be softened in the future.

The present book treats the problem of water softening from both a chemical and an operating point of view. It is prepared with especial reference to railroad water supplies, but the principles are, of course, equally applicable to other water supplies. It naturally contains no reference to American experience in this work, but the explanation of principles and methods seems very complete. The chapters on "Determination of the Amounts of Reagents" and "Testing the Softening" should prove especially valuable to any one having to do with a water-softening plant.

ELEMENTS OF SANITARY ENGINEERING. By Mansfield Merriman. Third edition. New York: John Wiley & Sons. 1906. 6 x 9 inches. 252 pp., 46 figs. $2.00.

The author says in his preface: "While this volume is primarily intended for the use of students in engineering colleges, its plan and arrangement are

materially different from those of other text-books on water supply and sewerage. The effort has been made to present the subject clearly and concisely in the smallest possible space, giving greater prominence to fundamental principles than to details of construction and operation. It is also hoped that the book may prove useful to municipal officers who have supervision of sanitary works as well as to the public in general, for it presents the guiding principles which should be observed in order to secure a pure water supply or an efficient system of sewerage."

The book is mainly descriptive. It is in no sense a text-book on the design of sanitary works of any kind. The titles of the chapters give a general idea of the subjects treated. They are: Sanitary Science; Water and Its Purification; Water Supply Systems; Sewerage Systems; Disposal of Sewage; Refuse and Garbage; Appendix.

This work should be an excellent text-book for imparting to students a general view of the whole field of sanitary engineering, and any person desiring a broad view of the general subject should find it very interesting and not difficult reading.

THE VENTURI METER AND THE FIRST TWENTY YEARS OF ITS EXISTENCE. By Clemens Herschel. Pamphlet. 6 x 9 inches. 48 pp. Published by Builders Iron Foundry, Providence, R. I.

While in a sense a trade publication, this little paper is so interesting as an historical review of the invention of this important hydraulic instrument, of its registers, and of the uses to which it has been put, that it well deserves mention in this place.

THE DISINFECTION OF SEWAGE EFFLUENTS FOR THE PROTECTION OF PUBLIC WATER SUPPLIES. By Karl F. Kellerman, R. Winthrop Pratt, and A. Elliott Kimberley. United States Department of Agriculture, Bureau of Plant Industry. Bulletin No. 115. Washington: Government Printing Office. 1907. Pamphlet. 6 x 9 inches. 47 pp.

A report of many tests of disinfection of sewage, at several places in Ohio, by the use of calcium hypochlorite, copper sulphate, and chlorin.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE WALTHAM RESERVOIR.

BY BERTRAM BREWER, CITY ENGINEER, WALTHAM, MASS.

[*Read September 12, 1907.*]

The Waltham reservoir is the fourth large reinforced concrete or mortar standpipe to be built in this country. It is the largest of the four.

The first structure of this character was built at Fort Revere, Hull, Mass., in 1902, of 1: 2: 4 concrete. The internal dimensions are 50 feet high by 20 feet in diameter, with a capacity of 118 000 gallons. This was a remarkable job, and very successful. It was constructed with very thin walls, only 6½ inches at the base and 3½ inches at the top. It has been fully described in the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, March, 1905.

About this time, or shortly after, in 1903, a reinforced standpipe of 1: 3 mortar was constructed in Milford, Ohio. This was 81 feet high by 14 feet in diameter, with walls 9 inches thick at the base and 5 inches at the top.

In 1905 the Aberthaw Construction Company constructed for the town of Attleboro, Mass., a large reinforced concrete standpipe 100 feet high and 50 feet in diameter. This was built of 1:2:4 concrete with walls 18 inches thick at the bottom and battered to 8 inches at the top, and holds 1 500 000 gallons.

The Waltham reservoir was built in 1906 of 1:2:4 concrete and is 35 feet high and 100 feet in diameter. The walls of this reservoir are 18 inches thick at the base, battered to 12 inches at the top. It holds over 2 000 000 gallons.

One writer, in a printed statement, described the concrete reservoir, built for the water department of the city of Waltham in the summer of 1906, as "a wonderful example of reinforced concrete construction." I may truly say, however, that this type of structure was only decided upon after careful preparation, covering a long period of time. This preparation included numerous laboratory tests, correspondence and consultation with several engineers, and several trips to Attleboro, including a big inroad upon the good nature of Mr. Snell.

The city government was reminded that the general public would not understand the details or difficulties involved in such a novel construction as that we proposed to undertake, and that it would be very easy for some misinformed or irresponsible person to infuse the public mind with the idea that the structure was unexpectedly leaky and dangerous, even though those in charge might know that such was not the case. Attention was also called to the fact that, as in previous structures of this character, the materials and the methods employed were such that it might require considerable time in which to stop up such seepage as in our best judgment could not be allowed to remain, and might preclude the possibility of absolutely watertight work.

Nevertheless, as we showed a saving of $2 300 over a steel structure of similar size, with no maintenance cost for the concrete, and were able to give good reasons for our faith in our plans and specifications, we were told to go ahead and were supplied with suitable funds.

Invitations were sent out March 13, 1906, and bids were opened March 22. On April 4, after extended negotiations, a contract was made with Simpson Bros. Corporation, of Boston, the lowest of four bidders, for the construction of the reservoir, for the sum of $25 786. Work was begun during the week beginning April 9, and the reservoir was ready to fill on August 28.

The bottom of the reservoir rests mostly on ledge and is 12 inches thick except under the wall, where it is not less than 3 feet 6 inches deep. It is reinforced with a layer of expanded metal near the surface to prevent shrinkage cracks. The floor is troweled to a granolithic finish. Bent rods were placed in this base spaced every 12 inches. They extend 6 feet into the base of the reservoir

and 3 feet up into the wall. Enough steel reinforcement was used in the walls to keep the tensile stress within a 12 000 pound limit. The rods were arranged in three rows up to 20 feet and then in two rows in the next 17 feet. The roof consists of a reinforced concrete slab 3 inches thick, supported by steel trusses radiating from a central, concrete covered, pipe column, which serves also as an overflow. These trusses are 3 feet 8 inches high at the outside ends and an ornamental enclosure wall was built up around and above them, making the total height of the side walls 43 feet. Except in the foundations and lower 6 inches of the floor, which were composed of a 1: 3: 6 mixture, the concrete was proportioned at the rate of 90 pounds cement to 2 cubic feet sand and 4 cubic feet stone and 5 pounds hydrated lime. (See Plate I.)

The walls were reinforced with 1⅛-inch round rods specified to fulfill the American Steel Manufacturers' standard specifications for railway bridge steel. The jointing of the rods was made, in every case, by a lap of 40 diameters. They were rolled on the ground to the required radius and occasionally tied at the ends. The cement was required to conform to the standards for Portland cement adopted by the American Society for Testing Materials. Most of the stone and all of the sand was screened from a gravel bank on city land not far from the site.

As most builders have found to their sorrow, there are certain inherent difficulties in manufacturing concrete which usually render it permeable to water. It was, therefore with great study and care in this particular that the specifications for this reservoir were prepared. Previous experience in the erection of the three concrete standpipes already mentioned, Milford, Fort Revere, and Attleboro, was carefully investigated. In this climate, it is perhaps not so much a question how to stop all percolation as it is to reduce it to so small a quantity as to avoid injury from frost. The peculiar, if not unusual, precautions taken to make this building a success may be grouped under the following heads:

First. The character of the sand and gravel which entered into the aggregate.

Second. Some waterproofing material or compound to be added.

Third. The method of placing steel and holding it in place.

Fourth. Forms.

Fifth. Making the joints and caring for the concrete as it set.

Sixth. Interior finish of walls.

Permeability tests were made with blocks of uniform section prepared from the materials to be used in the aggregate in different proportions in order to ascertain the most impermeable mixture. We determined to use gravel and sand from a bank on water works land not far from the site, the stones to be not over 1½ inches in diameter. Specimens were prepared with gravel from the aforesaid bank, mixed in the proportion of 1: 2: 4 with the ordinary bank sand and also with ⅔ bank sand and ⅓ fine sand. We concluded, after examining the various waterproofing materials on the market, to try two,— Medusa compound, manufactured by the Sandusky Portland Cement Company, and hydrated lime. Specimens having an admixture of 2, 4, 5, 7, and 9 per cent. of the weight of the cement were prepared and subjected to a pressure averaging about 70 pounds. We found that the use of a considerable proportion of fine sand was productive of good results, and that Medusa compound, when added to the extent of 4 per cent. of the weight of the cement, made a practically impermeable mixture. With the addition of hydrated lime to the extent of 5 per cent., the amount of water passing the concrete applied at 80 pounds pressure at the end of two months averaged 38 grams per minute in 2 specimens, and in a further test of 6 specimens where from 5 to 9 per cent. of the lime was added to the cement, the sand and stone being sifted in accordance with our specifications, 5 of the 6 specimens were absolutely impervious at 61 to 68 pounds pressure after standing for fourteen days.

Medusa compound is expensive. Its use to the extent of 4 per cent. in the body of the concrete would have added over $2 000 to the cost of the structure. Lime is comparatively cheap and effective, so we decided to depend upon those proportions of stone and sand which mechanical analyses of our materials showed to be the most dense, using hydrated lime in the concrete, to the extent of 5 per cent. of the weight of the cement, and lime and Medusa compound in the plaster and wash for the inside.

The specifications read as follows:

"All sand shall be clean, free from clay, loam, sticks, organic matter, or other impurities. In sand for concrete, not more than 5 per cent. residue shall be left on a No. 8 sieve, and the percentage passing a No. 50 sieve shall be so governed as to produce a concrete as watertight as possible in accordance with the instructions to be given by the engineer.*

"Sand used in plastering or grout must be of a fineness satisfactory to the engineer.

"Stone used in watertight work shall be of clean pebbles, screened from a gravel bank, and free from foreign matter. Clay or dirt adhering to the pebbles shall be washed from them before placing upon the mixing platform in hand-mixing or before placing in the mixer in machine-mixing. No stones in watertight work shall be more than 1½ inches in diameter and the stones shall be screened on a ¼-inch sieve in such a manner that by laboratory test not less than 15 per cent. nor more than 20 per cent. of materials shall pass a ¼-inch sieve.

"The sizes of the pebbles shall be so graded as to produce a concrete containing a minimum percentage of voids in accordance with the instructions given from time to time by the engineer. If the sizes of the pebbles as screened from the bank are not satisfactory to the engineer, it may be required that two sizes of stones shall be separately screened and measured.

"If preferred, broken stone, of hard and durable rock, of sizes satisfactory to the engineer, may be used for the foundations and that part of the reservoir above high water.

"In adding hydrated lime or other similar waterproofing ingredient or ingredients, the quantity prescribed shall be weighed or measured for each batch and shall be introduced into the mixer before adding any of the other materials and the mixer turned a sufficient number of times to form a milk of uniform color. If used in hand-mixed concrete it shall be well stirred into the water to be used in mixing the batch of concrete."

The steel supports for holding the rods were spaced 13.25 feet apart. They show very clearly in one of the cuts (Plate II, Fig. 2). The reinforcing rods, after being rolled very carefully to the required radius, were placed in the angles of these lattice-work supports. This method of supporting steel was worked out in detail by the contractor from suggestions made to him before the contract was signed, and proved entirely successful. With a lap of 40 diameters we secured, in each of the steel hoops, the ultimate strength of the steel at every point. The danger that some sections of the

* Fifteen per cent. was decided upon and used.

concrete might peel off at the outer line of steel rods was duly considered by us, and one of the precautions taken consisted in distributing the rods as much as possible through the section of concrete. In a structure of this character this possibility is a conclusive argument for the use of round rods.

Not only did we come to an early agreement with the contractor as to steel supports for the rods, but we made plans with him as to forms. These were erected in sections 3 feet high and about 5 feet long, 60 to the circle. Every outside form had a corresponding inside section which was tied to it with four ½-inch bolts extending through the wall. These bolts were in three parts; the middle, with the two heads into which it was screwed at either end, was permanently built into the wall, while the two outer parts were unscrewed from the outer ends of the heads upon removing the forms. The contractor built two complete sets of these forms, or enough for 6 feet of wall. The difference in lengths due to the batter of the outside of the wall was adjusted at the joints as the building progressed.

Rich concrete can be made waterproof much more readily by using well graded gravel. The rounded pebbles pack easily and readily produce a dense concrete. I believe that lime also is a valuable adjunct. The greatest care in selection of materials, however, cannot overcome the evils due to careless mixing or placing, and the bane of such extensive operations in watertight work still remains in the difficulties connected with making tight joints where new work joins the old. The following specification was devised to cover this point:

"Before laying concrete on rock surfaces the latter shall be swept clean of all *débris* and dirt and *wetted* when directed.

"Where one day's work joins another, or when new concrete or a plastic surface is added to old concrete which has begun to set, special precautions must be taken. The old surface shall be thoroughly cleaned of all dirt and scum or *laitance*. This *laitance* shall be entirely brushed out with steel brushes, or other implements satisfactory to the engineer, down to hard material. The old concrete when cleaned of all *débris* and dirt shall be carefully wet down and a thin layer of neat cement grout thoroughly brushed in and the new concrete added before the grout has time to set.

FIG. 1. REINFORCEMENT AND FORMS AT BASE OF WALL.

FIG. 2. LOWER PART OF WALL, WITH SUPPORTS FOR REINFORCEMENT RINGS.

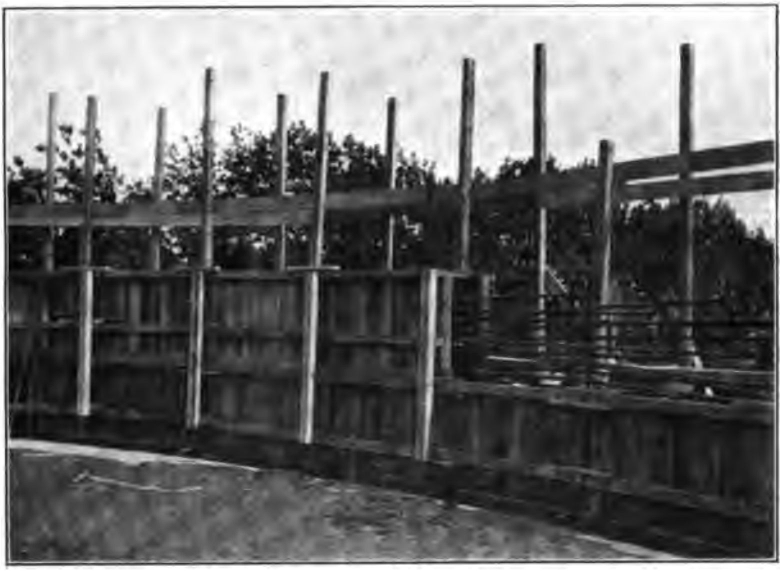

FIG. 1. METHOD OF SUPPORTING WALL FORMS.

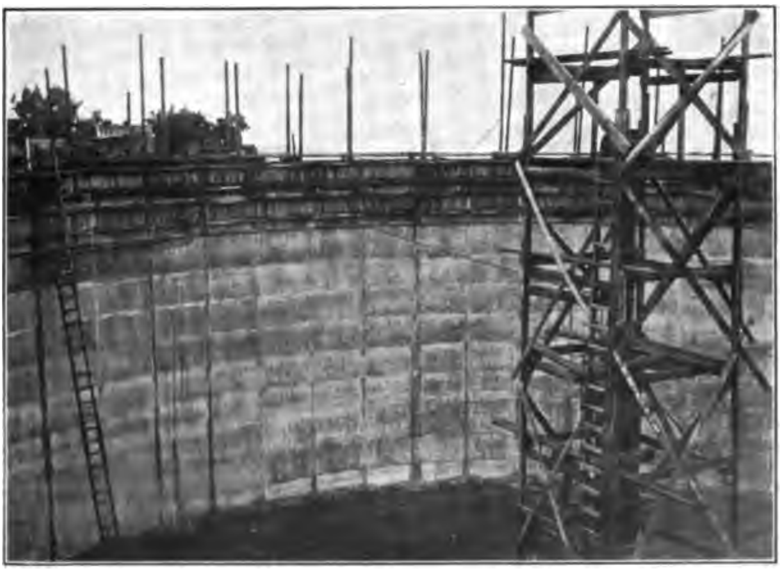

FIG. 2. INTERIOR OF WALL DURING CONSTRUCTION.

"As an additional precaution for securing a good bond, a groove at least 4 inches deep and 3 inches wide shall be constructed in the top of any portion of the wall allowed to stand and set."

New concrete was covered and wet down daily for a month, but, except for a small quantity of water in the bottom, no attempt was made to fill the reservoir until it was completed.

We determined, if possible, to get a waterproof concrete and in no wise to depend on the inside coating. That did not prevent, however, a thorough investigation of possible methods and the use of such as we thought best. The Hull and Attleboro standpipes were plastered, in the first case successfully and in the second case the Sylvester coating of soap and alum was finally resorted to, to make the structure satisfactorily tight. Our specification as to finish of floor and walls was as follows:

"A granolithic finish is to be troweled on to the surface of the floor by skilled mechanics at the time it is built. Said finish shall be carried up to the top of the curve at the junction of the floor and wall. Special care shall be taken to avoid any joints in the work.

"The contractor shall remove forms as soon as possible, and shall immediately treat the inside surface of the walls as follows: He shall remove all loose or unset material from the surface. He shall use special care at the joints and between layers of concrete, and, after cleaning them out and jointing with neat cement, the wall for a distance of 9 feet up from the top of the curve at the junction of the floor and wall shall be plastered by skilled mechanics with mortar mixed and placed as directed by the engineer. For the remainder of the wall, after cleaning and jointing as above specified, he shall apply two thin coatings of Portland cement grout and brush each in thoroughly, taking special pains at the joints."

For plastering, a mixture of 1 of cement to 3 of sand was used with the addition of hydrated lime to the extent of 10 per cent. and Medusa compound to the extent of 3 per cent. of the weight of the cement.

The brush coat consisted of a 3 to 2 mixture of cement and sand with 5 per cent. of the Medusa compound added.

The 24-inch inlet pipe, which, by the way, also serves as an outlet, is located half way between the wall and the central column. It is flush with the surface of the floor.

In a tank of this size we do not consider that there is any danger from ice. Ice forms in such fashion, little by little, that

the theoretical bursting pressure could not be applied at any one spot at any one time. The level of the water is constantly changing, and, in an underground supply like Waltham's, the water is comparatively warm in cold weather.

A candid statement of his mistakes by an intelligent man is often of more value than whole pages of description. I can truly say, however, after one year's use that there are very few mistakes to record; certainly, every structural difficulty was met as we expected.

There are two points which I desire to mention:

First, we allowed the contractor to use bolts with round shoulders to tie the forms together. After the wall was built and when unscrewing the outside sections to remove forms, the workmen, largely owing to their shape, occasionally jarred or moved and sometimes turned the permanent section, with the result that when the tank was filled, at many of these bolt holes there were noticeable damp spots. At the present writing these have practically silted up. We should have insisted on the square-headed bolts originally agreed upon.

Except in rainy weather, when it is not so important, we found that we could build 3 feet of wall in two and one-half days, and this should have been the limiting time. In one case, owing to delay in assembling a larger steam plant, the contractor allowed a section of old work to stand for five days in hot, dry weather before building on new wall, and that particular joint has shown the most seepage.

The body of the wall is not, and never has been, porous. The seepage, which has been very slight, and mostly such as the sun will dry up, has been confined to a very thin film at the joints, and to the bolt holes. Nothing has been done to the reservoir since it was first filled except that an uninspected third brush coat was applied at the joints by unskilled labor. Soon after the reservoir was put into use there was a considerable efflorescence, and a noticeable stalactite formation began to appear on the outer wall. I believe that the excess of free lime is certainly closing up the pores. The seepage has grown markedly less with use and no ill results followed the extreme cold of our last winter.

As already hinted, the problems connected with a large water-

FIG. 1. PLACING ROOF TRUSSES.

FIG. 2. VIEW OF COMPLETED RESERVOIR.

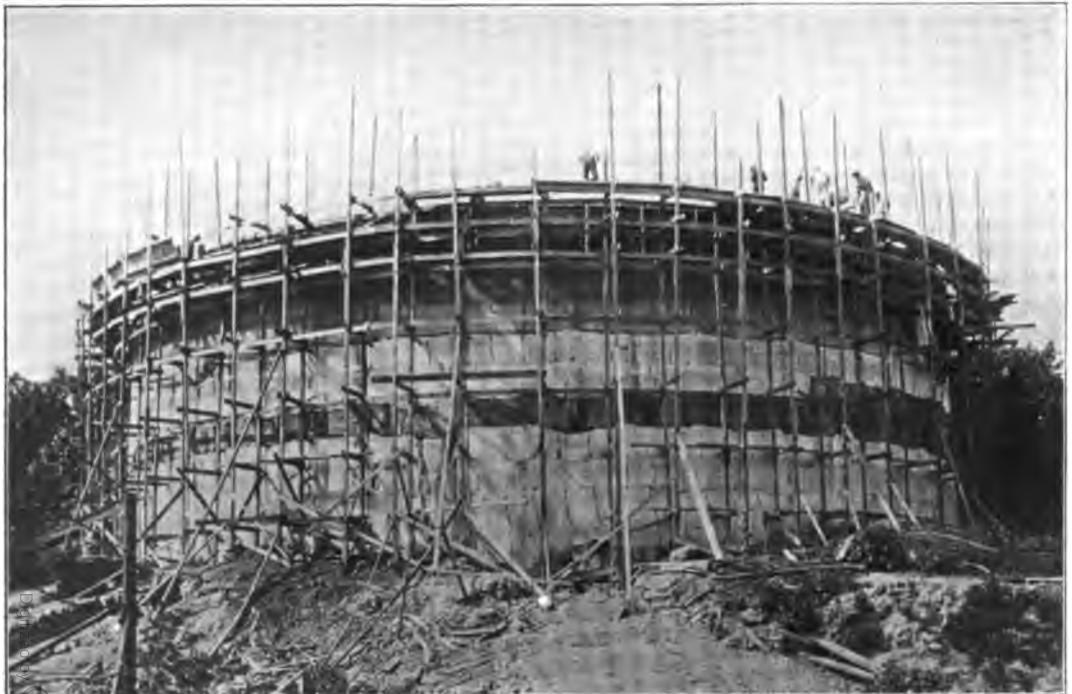

FIG. 1. GENERAL APPEARANCE OF RESERVOIR DURING CONSTRUCTION.

FIG. 2. LIME FORMATIONS ON SURFACE.

proof concrete structure are very different from those incidental to the small tank. In the fall of 1906 I built a plain concrete tank in the ground, 50 feet from and below the river, with city labor, in which the concrete itself has been from the first absolutely watertight, and has shown no seepage whatever. This tank is 18 feet in diameter and about 18 feet deep, with 10-inch walls.

Two inspectors were employed at the reservoir while work was going on. One was stationed at the mixer and the other attended to the work on the wall. These men were not only interested and faithful but the principal inspector was especially skilled in concrete work. The inspection was of the best and is, I consider, an essential feature of our success.

The architectural features were carefully planned. We fixed upon good proportions to begin with and decided, after thorough investigation into a practical way to secure it without additional cost, upon battered walls. No difficulty was encountered in securing this important architectural effect, and, as a matter of fact, the amount of concrete, and therefore the cost, was considerably reduced thereby.

Mr. J. R. Worcester, the consulting engineer, who is a fellow-townsman, shared with me the responsibility for the design and specifications for this work.

DISCUSSION.

MR. T. H. McKENZIE.* May I inquire of Mr. Brewer whether the reservoir is built on earth or rock bottom?

MR. BREWER. It was mostly ledge.

MR. McKENZIE. What was the thickness of the bottom?

MR. BREWER. Twelve inches.

MR. McKENZIE. Can you give us any idea what was the cost per cubic yard of such a tank, including the bottom? That is, a sort of lump estimate of how much it cost per cubic yard, including everything, the forms and reinforcing.

MR. BREWER. I should say from $20 to $25 per cubic yard, including the entire cost of the reservoir as completed. Of course I did not estimate it in that way. A remarkable thing in connec-

* Civil Engineer, Southington, Conn.

tion with that question was that the contract was let for within a few hundred dollars of my estimate.

MR. MCKENZIE. Could you tell us what was your estimate?

MR. BREWER. I stated the cost in my paper; it was $26 000.

MR. MCKENZIE. Could you tell us the dimension?

MR. BREWER. One hundred feet in diameter, 35 feet to high water, 43 feet over all.

MR. LEONARD METCALF.* Do you remember, Mr. Brewer, what that amounted to per cubic yard in round numbers?

MR. BREWER. I estimated the wall concrete, aside from the forms in steel, as about $8 for the work.

MR. METCALF. I mean including the steel; in other words, the total cost per cubic yard of the structure.

MR. BREWER. Of course a very different unit price would apply to the bottom.

MR. METCALF. Yes; that should be separate, of course.

MR. BREWER. The concrete in the bottom cost about $7.50 per cubic yard, while that in the walls and roof cost about $23.

MR. METCALF. Mr. President, I have been immensely interested in the discussion of this structure, which it seems to me is a very creditable one indeed, and I should like to ask Mr. Brewer about the method of preparing the joints before depositing the fresh layer of concrete on the old. He spoke, I believe, of removing the forms as soon as possible and putting on the plaster coating on the inside. Did he at that time have the surface of the concrete washed down and cleaned, or was that done after the new forms were erected, and just prior to applying the concrete? I ask that for the reason that inside of such narrow forms as these, and with the steel in place, I should think it would be pretty difficult to do that work after the forms were in place.

MR. BREWER. The cleaning was always done before the new forms were erected. The wall, as soon as sufficiently set, was cleaned, thoroughly cleaned, with steel brushes. Then it was washed out very thoroughly with water from the hose, — we got it all as clean as we possibly could, — and then new forms were added. By the time the contractor was ready to fill the new forms, more or less dirt had collected from some cause or other.

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* Consulting Engineer, Boston, Mass.

We were very careful to clean this out, give the old concrete another thorough washing, and make sure that it was all right before starting the new wall. Then, just before putting the new concrete on to the old, the grout was applied.

MR. METCALF. That was done with brooms, or something of that sort?

MR. BREWER. Yes, sir.

MR. METCALF. Will you inform us what was the size of the largest slab used in the roof?

MR. BREWER. It shows on the plan — about 12 feet. The roof was designed for a load of 90 pounds, 60 pounds dead and 30 pounds live load.

MR. METCALF. You used a thickness of 3 inches, figuring on a slab of 12 feet?

MR. BREWER. Four inches in the center slab; 3 inches elsewhere.

MR. H. K. BARROWS.* May I inquire, has the tank been filled?

MR. BREWER. It has; yes, sir. It has been in use now nearly a year.

MR. BARROWS. There is no settlement between the earth foundation and the ledge foundation, as far as you know?

MR. BREWER. No, sir.

MR. WM. F. CODD.† I should like to inquire, in case the standpipe should leak steadily, whether the rods would be likely to rust and lose their strength.

MR. BREWER. I don't think we would allow it to "leak steadily." We don't expect it to leak. It hasn't leaked this year, and after going through last winter I don't think it ever will. There are many things we might do to it if it did leak to such an extent as to cause any apprehension.

MR. KENNETH ALLEN.‡ Mr. President, about two years ago I built a reinforced concrete coal pocket similar in some respects to this tank. It was 30 feet in diameter and 33 feet high inside, with a pyramidal top and conical bottom, supported on two annular cylinders, and the capacity was 400 tons. Of course it wasn't necessary to have it watertight.

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* Civil Engineer, Boston, Mass.

† Superintendent of Water Works, Nantucket, Mass.

‡ Division Engineer, Baltimore Sewerage Commission.

After placing the first set of rather long vertical reinforcing bars we had a very high wind without any apparent effect, but shortly after we discovered, by hammering, that three or four pilasters in which these were placed were not sound. Before completion the concrete in these was cut out and we found that the steel reinforcement had separated from the concrete. The material was in good condition and hadn't cracked, but if it had done so and if the structure had been designed to hold water, the result can be imagined. After noting the above defects greater precautions were taken to keep the bars from swaying, the pilasters were repaired, and the work finished without further trouble.

The proper securing of reinforcing rods from vibration is very important, especially in a tank of this kind, and I was interested in the very neat device used by the contractor for this purpose in Waltham.

Mr. Brewer. In answer to the question about the possibility of the steel rusting, in the photographs of another reservoir that I have shown I think that steel was exposed two or three months, if not longer, — may be four or five, — and when I saw it there was no sign of rust on it. It was wet, quite wet, at the time. I suppose there is a safeguard in the alkaline nature of the water that passes through concrete that prevents rusting. You will find the facts stated in the account of the Attleboro reservoir in the Journal.*

Mr. McKenzie. I think the most uncertain thing about reinforced concrete tanks is the matter of the life of the steel reinforcement. They will have to be used a sufficient length of time to determine the life of the steel rods. I had an experience in Meriden taking up a cement and sheet-iron pipe of the very best make. Our friend Mr. Bishop had charge of making and laying it. Nine years after they were laid we took them up and a large proportion of the sheet iron that was originally a quarter of an inch thick, or thicker, was entirely rusted out. The cement was from 2½ to 3 inches thick on the outside and from 1½ to 2 inches thick on the inside. Where the cement had adhered to the pipe it was perfectly bright, good, and strong, and where the cement had not adhered to the pipe there was simply a film of rust between

* September, 1906.

the two coatings of cement. Three fourths of the pipe was just a film of rust; practically no iron there at all. I don't know whether there would be the same result with a tank, whether the concrete would be sufficiently porous in a tank like the one that has just been described, so that the rods would corrode in any reasonable length of time. I don't believe any one can tell us what would be the life of the tank, on account of the porosity of the cement.

PRESIDENT WHITNEY. We should like to hear from Mr. Maury on the subject.

MR. DABNEY H. MAURY.* Mr. President and gentlemen: I am afraid what little I may have to add to this discussion is not directly in the line of Mr. Brewer's very interesting paper for the reason that the reinforced concrete reservoir which I shall mention is not of exactly the same sort as Mr. Brewer's. His structure was built as a standpipe and depended upon the ultimate strength of the reinforcement to resist rupture. The structure I have in mind was built as a wall, with a gravity section. Yet it may be of interest here to say a little about it because it is remarkable for at least two things: In the first place, for its size, which was 300 feet inside diameter, 15 feet deep at the wall, and 25 feet deep at the center; and in the second place, for the conscientious care which was displayed by the contractor in the construction of a piece of work on which he was making no money.

A third feature which caused some comment was the small cost per million gallons of capacity of this reservoir. In addition to the reinforced concrete in wall and bottom, the work included 30 000 cubic yards of excavation and embankment; 100 feet or so of 24-inch pipe, with a number of gates and fittings of the same size laid in quite a deep trench; and 1 000 feet of heavy fence, made of wrought-iron pipe and fittings. The entire cost of the whole structure was $34 000, or $3 400 per million gallons capacity, which I believe is unusually low.

The advertisement for bids specified that bidders should submit their own plans and specifications for a 10 000 000-gallon reservoir, and there were practically no other limitations. The bids ran all the way from $27 000 for an earth reservoir to $55 000 for a heavy

* Consulting Engineer, Peoria, Ill.

concrete gravity section wall with a heavy bottom. The bid of the firm which employed me to prepare plans and specifications was $37 500. The firm was afterwards jewed down to $34 000, and then was awarded the contract. It completed the work in 100 days, giving bond to keep the reservoir tight for five years. The reservoir is apparently in excellent condition after two hard winters.

I had nothing to do with supervising the construction except that I went down occasionally to see what was going on. Some rather heroic tests were applied to the work during construction by the mayor of the city for which it was built. For instance, there was an embankment on the outside of the wall, and this embankment was raised to the height of the wall, at first back a little distance from the wall; then, when the concrete was only about seven days old, the space between wall and embankment would be filled in with water and the mayor then requested the contractor to dump the remaining part of the embankment, out of a bucket holding a yard and a half, into this water, so that he could see whether the wall was leaky. This test was continued all around the 950 feet circumference of the wall, and there was dampness on the other side in but five places, and in only one of those places did this dampness amount to a trickle, which did not exceed 3 drops per minute.

The wall was 3 feet in thickness at the base, 1 foot at the top, 15 feet high on the outside, and with a toe and heel which together made up a base of about 11 feet in width, forming a gravity section. I am unable to give from recollection many of the details as to the mixture.

I might mention, perhaps, as a matter of interest, the way in which the forms were built. They were built in 10-foot circumferential sections, the outside and inside forms fastened together. Eleven of these forms, making up a distance around the inside of 110 feet, were set up in the beginning, and the concrete was placed in the forms from the center toward the end in thin layers, so as to give as long a joint as possible. Then, as the work rose inside the form to the top of the wall, the center forms would be taken out and moved to the ends and the work continued in one piece all the way around until the wall met on the other side. The

bottom was 5 inches in thickness and was reinforced with quarter-inch rods spaced 6 inches center to center. They were roughly woven in mats about 25 feet square; one of these mats would be laid down and then filled with concrete. There was a top dressing of a half inch of cement, sidewalk finish, and of a richer mixture, over the bottom. I haven't been able to learn that there is any leakage.

A description of this reservoir was published in the *Engineering Record* of March 3, 1906.

Mr. W. C. Hawley.* Mr. President, I read a paper before this Association some years ago and detailed methods used to secure watertight concrete for the lining of reservoirs. I have had no experience in work such as has been described here, and I would only say that the work which I described in my paper has proven very satisfactory. The only difficulty appears to be in getting a watertight joint between the blocks of the concrete. On the last reservoir which we built we used a joint of asphalt, the concrete being placed against a sheet of steel one eighth of an inch thick, the steel sheet withdrawn before the concrete had set hard, and the space filled with asphalt or what is known as "mineral rubber." That has been very satisfactory, especially on the bottom; it is not quite so satisfactory on the slopes.

President Whitney. Wouldn't it be of interest to have some expression of opinion as to the probability of the steel reinforcement oxidizing in a reinforced structure? Mr. Hawley, we have just heard from you, but I should like to hear from you in regard to that matter. I would like to ask your opinion as regards the probability of the steel oxidizing.

Mr. Hawley. I think, Mr. President, that it depends very largely on how the concrete is placed; whether it is given a fair chance to get a good bond with the steel. The old idea of placing concrete so dry that it had to be tamped has passed away, and nowadays I think it is generally recognized as far better practice to make the concrete so wet that it must form a solid mass. That is what I have done. Our men in placing it wore rubber boots, and they would sink into the concrete nearly to their knees. We had splendid results.

* General Superintendent Pennsylvania Water Co., Wilkinsburg, Pa.

As a matter of interest in this connection I might say that a few years ago the abutments in a bridge on the Monongahela River were torn down. Any one familiar with the water of the Monongahela River knows that at times it is frightfully acid from the sulphur of the mines. When one of the stones was taken from its bed a steel cold chisel was found imbedded below the stone in the mortar of the joint. It had been there, I believe, for some thirty odd years, where this acid water certainly would have destroyed it if it could have reached it, but there was not a sign of rust on the chisel; it was perfectly bright and clean. I think that is pretty good evidence of the protection of steel where properly bedded in the concrete.

PRESIDENT WHITNEY. The question has been raised, Mr. Hazen, in regard to the probability of the steel reinforcement ceasing to have any special effect to strengthen a cement concrete structure eventually. What is your opinion in regard to that? What is your opinion in regard to the oxidization of the steel?

MR. ALLEN HAZEN.* I don't know that I have any special information on that, Mr. President.

PRESIDENT WHITNEY. You are supposed to have information on all subjects, Mr. Hazen.

MR. HAZEN. I was reading a description of reinforced concrete structures to hold water under pressure the other day, and this description told about some cracks that opened, and the steel, of course, prevented their opening very wide, and the cracks were calked, and they went on using the structure. Now, generally speaking, it is supposed that concrete will protect the steel from rusting, but it seemed to me in this case that the fact that a crack opened across the line of the steel necessarily meant that the concrete had slipped on the steel for a considerable distance on either side of the crack, and the steel crosses the crack and is certainly exposed to the water and is likely to rust away there just as it would do in the open. I wondered if the structure would not be destroyed after a while by the rusting away of the steel at these places even though it was generally protected. My feeling in building concrete structures to carry water under pressure has been to build them so that there would be definite cracks; or, in other

* Consulting Engineer, New York, N. Y.

words, build the cracks or joints and let those cracks open and protect them with some kind of an expansion joint.

In the case of the reservoirs at Watertown, N. Y., which were built of concrete backed up with loose stone fill — which was the only fill available — the watertightness depended on the concrete and on nothing else. The walls were built with some reinforcing, and the cracks in the joints that opened were calked in cold weather with oakum. That made the work substantially watertight, and it has so remained. The oakum is compressed in summer when the masonry expands, but in some way it seems to expand again in the winter, and keeps the crack reasonably filled so that it does not leak. It clearly does not do to calk the crack with cement, because, if this is done, in warm weather the corners spall off, and that leaves the crack in worse shape than it was before.

Mr. Walter H. Richards.* Mr. President, I remember twenty-five or thirty years ago there were plenty of engineers that were telling how to protect the iron in a water pipe with cement, — what to do for the protection of the iron in cement-lined pipes. There are a number of us who have found out we were mistaken since that time, and perhaps it may be so with reinforced reservoirs. We can't tell, but it occurred to me, while this paper was being read, that it would be very unfortunate if the reservoir should freeze over with any considerable thickness of ice. I presume that is amply provided against, but still it seems to me that there is a liability of its being unable to resist the ice pressure. I should say my prayers on a very cold night, anyway.

Mr. A. A. Reimer.† Mr. President, I thought that Mr. Fuller was going to give us his paper on waterproofing, so I was holding back what I wished to say. On the East Orange system we have two reinforced concrete structures that may be of interest in connection with this subject of waterproofing. One of the structures is a standpipe 50 feet high and 10 feet in internal diameter. The first 10 feet above ground is battered outside from 18 inches thick at ground level to 12 inches, the main shaft above this being straight 12-inch work. The roof is conical in shape, of 3-inch

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* Engineer Water and Sewer Departments, New London, Conn.
† Superintendent of Water Works, East Orange, N. J.

concrete, covered with red tile for the sake of appearance. The Angus Smith process was used in waterproofing this structure, but unfortunately we have very little use for it, so have not been able to determine through the winter time — the most serious part of the year — the value of that waterproofing.

The other structure is a 5 000 000-gallon reservoir, with 12-inch walls strengthened by inclined buttresses 10 feet on centers. The reservoir wall has a heavy embankment on the outside, and in this wall the Angus Smith process was used as waterproofing. Evidences of leakage became apparent soon after the reservoir was put in service two and one-half years ago. We were never able to determine whether the leakage was from the joints or by means of general seepage through the walls because of the embankment outside, but we had collecting drains around through the embankment to drain the embankment, and during all the dry periods we had a large amount of water coming from those drains, proving that there was a serious leakage from the reservoir. The floor of the reservoir was leaking also, this being proved by the drains laid under the reservoir.

Because of these facts we took up the question of waterproofing this past summer, and after careful study I decided on the Sylvester process as being the most satisfactory for our purpose. We have treated the walls and floor of the reservoir with this process and have met with what might be called absolute success. There seems to be no seepage or leakage from the drains now, and we believe this condition will be permanent. If the work on the old Croton gate chamber may be cited as a criterion we should find our reservoir tight for many years to come. I speak of this as showing what repair work can be done with the Sylvester process.

Mr. Metcalf. How old is the Croton work?

Mr. Reimer. The dam is about seventy years old, but the waterproofing I speak of was done about forty years ago, I believe. The gate chamber is of brick.

Mr. Hazen. I don't know about that case. We have never experienced any difficulty in building concrete blocks so that they would not leak. I think if concrete is mixed wet, and is of the proper mixture and well worked down, the blocks themselves are tight. The only leakage we are afraid of is the leakage between

the blocks, or leakage from cracks that come where the length of a structure is so great that there are temperature cracks, or cracks from any other cause. Structures of some length, which may be as great as 100 feet, can usually be built and reinforced so that they will not crack. But with large structures cracks must always be expected.

Mr. Reimer. The Angus Smith process was used in the work as it was constructed, but the Sylvester process is what we used this past summer in making the structure finally watertight.

Mr. Brewer. I should like to know if anybody here knows about the Sylvester process, as to how long it has been actually proven effectual. While on my feet I might add that it seems to me that this question of the rusting of reinforcing rods buried in concrete is very different from the rusting of the wrought-iron shell of cement pipes such as many water-works men are used to and are sorry therefor. I don't think you can make a comparison between methods of doing one and the other. That ought to be borne in mind when you criticise the placing of rods in a concrete wall a foot or eighteen inches thick.

Mr. A. Prescott Folwell.* A reservoir which I built some years ago convinced me that in many cases all you need to secure imperviousness is well-made concrete; at least, that has been my experience. I have always borne the Sylvester process in mind, but never had occasion to use it. The reservoir referred to is about 200 by 300 on the water line, and the only application which I made, in order to make it tight, in addition to taking pains with the concrete, was to give it three substantial washes with neat Portland cement and water, each one being dried thoroughly before the next wash was applied. On filling the reservoir there was no leakage perceptible. We didn't take any account of evaporation or dew-fall, but marks were made on the side of the reservoir, — a very fine mark with a lead pencil, — and after watching for over a month we could see no perceptible rise or fall in the reservoir. There had been no rain, by the way, during that time, and how much effect the dew and evaporation had in counterbalancing each other I couldn't say. Another smaller reservoir, 1 500 000 gallons capacity, was built in the same way. That a'so

* Editor *Municipal Journal and Engineer*, New York, N. Y.

was, as nearly as we could ascertain, absolutely tight. We never found any leakage in that whatever.

I was somewhat proud of the larger reservoir for another reason, perhaps a little apart from the watertightness of the concrete, and that was, there was about three feet of an embankment on top of the bed rock at one end and it was all embankment at the other end. In other words, from half to two thirds of the reservoir was excavated out of rock, and the other end of the same reservoir was on dirt having a depth of 10 or 15 feet, possibly more, in thickness above the rock; but at the point of junction between the earth bank and the rock no cracks appeared in the concrete lining, so solidly had the embankment been compacted. The concrete was mixed 1: 2½: 5, of broken limestone. The pressure was about twenty feet head. A large number of analyses were made of the broken stone and sand to determine what percentage of the various ingredients which were used in the mixture should be taken. As I say, we got apparently a very tight concrete and one which did not crack. The cement wash was very thin and did not form a coating to peel off later.

The reservoir has been in use two or three years now and I believe has never leaked at all. I have made a great many smaller tanks, giving the same wash of Portland cement and water, and if there was any trouble it was because of cracking and not of perviousness.

Mr. F. L. Fuller.* Mr. President, I think concrete reservoirs are apt to improve in tightness with age and use, even if no interior surface application is made. Much, however, depends upon the quality of the concrete and the care with which it is placed.

I think a free use of very finely ground neat Portland cement, mixed with water to about the consistency of paste, thoroughly applied with a brush on the inside surface, is very effective. No doubt by allowing the original inside surface to be rather rough and, after removing the centering, putting on a thin, thoroughly troweled plaster coat of neat, or perhaps 1 to 1 Portland cement over the sides and bottom and then adding the brush coats, a reservoir can be made practically watertight. The Wellesley concrete-covered reservoir, built under the supervision

* Civil Engineer, Boston, Mass.

of F. C. Coffin, in 1897, was tested in January, 1907, by closing the outlet valve into the distribution system for the space of twenty-three hours, and no drop took place in the water surface, the reservior being nearly at high-water level.

A number of other concrete reservoirs tested by me while new showed some leakage. No doubt a portion of the drop in the water surface was due to the absorption by the dry concrete of a certain amount of water. By the application of brush coats on the bottom and side, or in some cases of a thin plaster coat on the bottom, before the brush coat was put on, the leakage was materially reduced. After a reservoir has been put into service, it is, of course, difficult to test it unless it is one of a set which can be temporarily disconnected from the distribution system, but I am of the opinion that most of these concrete reservoirs would be found substantially tight.

It is often advisable to place an underdrain beneath a reservoir to take away the ground water in the soil where the reservoir is located, thereby relieving the bottom of an upward pressure, due to the level of the ground water above the reservoir bottom.

During dry weather the amount of ground water decreases and may fall below the level of the bottom of the reservoir. It then furnishes a means of measuring the amount of leakage from the reservoir, if any. In two instances, where used by me there has been no flow of water from the underdrain during the dry season, indicating the tightness of the reservoir.

I have noticed in a section of cement-lined water main, newly cut out, something in the nature of a thin, transparent slime adhering to the surface of the cement forming the inside of the pipe. The same formation may exist on the bottom and sides of a concrete reservoir, and might be seen, provided the reservoir could be emptied suddenly and inspected before the surface had time to dry. This slimy coating may have a decided tendency toward making the surface impervious to water.

Concrete to be impervious to water when set should be mixed quite wet and after being dumped should be worked into place and manipulated so as to make as nearly as possible a solid mass with no voids. This is impossible with dry concrete. Wet concrete should be worked with tools similar to a spade or a thin

and rather narrow chisel-shaped piece of iron or steel connected to a straight handle, rather than the ordinary flat cast-iron tamper having a considerable area.

The agitation with these tools tends to dispel air bubbles and to settle and thoroughly mix the aggregates till the mass is practically solid.

The Sylvester method or process of waterproofing does not appear to have been largely used in this vicinity. In the only instance with which I am familiar, it did not prove very successful.

MR. ALLEN. Some years ago I put in a system of sewers for the military post at Fort Supply, I. T. As there were no roads, and as some of the trenches were very shallow, a number of flush tanks were almost entirely above ground. They were built of brick with a $\frac{3}{8}$-inch coat of natural cement plaster on both inside and outside painted with neat cement grout. Several of these persisted in seeping to a slight extent. Portland cement was not available, so I used the Sylvester process on the inside of those that gave trouble, and it was entirely successful.

MR. MCKENZIE. Mr. President, I have had a similar experience to Mr. Fuller's with reference to washing reservoirs with neat Portland cement, applied with a brush. The year before last we built a dam some 16 feet high, using iron beams for reinforcement, and applied Portland cement wash to the face of the walls for waterproofing it, two coats, to make it absolutely tight.

Last year we built another one, 19 feet in height, and the wash was applied with a brush, — neat Portland cement, — and it is absolutely tight.

I am very glad to learn that the Boston engineers have found out that dry concrete doesn't make a tight wall. Only a few years ago the Boston engineers practiced making concrete very dry, — so dry that it couldn't possibly be consolidated. But I understand that they know now that they can use it wet.

MR. BREWER. Referring once more to the discussion as to the life of steel in a concrete structure built for holding water, I might add that that phase of the proposition furnished us very little anxiety. The following suggestions may, however, be of value:

In the Waltham reservoir the steel was thoroughly coated with and imbedded in a very alkaline semifluid substance which has

since become practically an impervious rock. There is no space around the metal for the accumulation of rust, or, to put it in another way, the space needful for oxidization is lacking. We must, therefore, conclude that oxidization cannot proceed very far with the steel properly embedded in the concrete.

If we accept the most recent explanation of the rusting process, that corrosion is always due primarily to electrolytic action, we may summarize as follows: Oxidization cannot occur to any extent, because of:

First. The alkalinity of concrete.

Second. Lack of space.

Third. Limited supply of water.

Fourth. Limited supply of oxygen.

RECENT IMPROVEMENTS TO THE WATER WORKS AT PEABODY, MASS., INCLUDING PUMPING PLANT AND DISTRIBUTING RESERVOIR.

BY FRANK A. BARBOUR, CIVIL ENGINEER, BOSTON, MASS.

[*Read September 11, 1907.*]

The Peabody water works were originally purchased from the Salem Aqueduct Company, one of the oldest in the country. The history of these works begins in December, 1796, the year the Boston system was introduced, when a meeting of subscribers of the Salem and Danvers Aqueduct Company was held at the Sun Tavern, Salem, Mass. At this meeting a committee of three was appointed to procure an act of incorporation, to make all contracts for logs and boring of same, and to contract for land through which the aqueduct was to pass. The necessary funds for starting the work were procured by issuing one hundred shares of stock at $40 per share. A petition for incorporation was presented to the General Court in January, 1797, and an act of incorporation was signed by Gov. Samuel Adams on March 9 of the same year. Work was immediately begun, the pipe line consisting of logs with a bore of 3-inch diameter, and by August the work was so far completed that the directors were authorized to dispose of the privilege of drawing water from the aqueduct for a term not exceeding one year, under such terms and restrictions as they should judge proper. The rate for a family having one post was $5 annually, to be paid semi-annually.

In 1804, after the company had expended $44 000 on the works, it was found that the supply through the 3-inch log was inadequate, and it was ordered that a new log be laid for the aqueduct with a bore of not less than 5 inches.

The first iron pipe, which was 6 inches in diameter, was laid by the company in 1834. In 1850 a 12-inch iron pipe was laid from the source of supply to Federal Street in Salem. In 1866 this 12-inch pipe was extended to a point opposite the Market House in Salem. This 12-inch iron pipe is to-day the means of supplying

a small service district in Peabody. After 1852 all extensions were made with cast-iron or cement-lined iron pipe instead of logs. In 1865 a 16-inch cement-lined pipe was laid from the reservoir to Federal Street, Salem. To-day this pipe is one of the principal distributing mains of the town.

In 1873 the town of Peabody purchased the works and franchise from the Salem Aqueduct Company for $125 000. At the time of the purchase one hydrant, located at the Square and attached to the 12-inch pipe, was the only fire protection afforded to Peabody by the system.

Originally the works were planned to furnish Salem and Peabody with water by gravity from Spring Pond. After their purchase by the town, higher pressure being desirable, a pumping station was constructed at the corner of Foster and Washington streets, the water being drawn from the 16-inch gravity main and, after passing through the pumps, being again returned to this same main. In 1882 a standpipe 60 feet in diameter and 23 feet high was erected on Buxton Hill, with its high-water mark at elevation 180 above mean low tide.

The pumping plant consisted of two Worthington pumps, one pump being a horizontal duplex, compound condensing type, rated at 2 500 000 gallons capacity, the other a horizontal duplex simple type of 2 500 000 gallons capacity. The boilers were two in number, 15 feet long, 6 feet diameter, rated capacity 95 horsepower, and when operating carried about 65 pounds steam pressure.

In 1902 the consumption had increased to a point where the capacity of the pumps was not sufficient to fill the standpipe without running well into the night, and the water stored in this way was so far depleted by the night draft that but little remained at the time of starting the pumps the next morning. It was therefore evident that pumps of greater capacity were needed and, if the pump run was to be limited to a reasonable number of hours per day, that a larger standpipe or a reservoir, capable of holding a supply sufficient for the town during the time the pumps were not in operation, must be provided. It was accordingly recommended that a pump of 5 000 000 gallons daily capacity be installed in a new station, located at the source of supply, thus

doing away with the long pipe line between the supply and the old station which, while originally a pressure main, had, under the increased draft, operated of late years as a suction pipe.

It was further decided to construct a circular masonry reservoir on Lookout Hill, of 2 500 000 gallons capacity, with its high-water mark at elevation 220, or 40 feet above that of the old standpipe, and to connect this reservoir with the distribution system by a 20-inch supply main 10 000 feet long, extending to the corner of Foster and Washington streets, the location of the old station.

It is intended in this paper to briefly describe the pumping plant and reservoir which, while involving nothing of particular merit, are perhaps of sufficient interest to justify their being made matters of record. In the experience of the writer it has often appeared that while descriptions of large works can be readily found, smaller plants have been more or less neglected, and it is often difficult to obtain suggestive plans and information of the class of work demanded for a community of ordinary size.

Incidental to these improvements in the distribution system, some work was done in bettering the quality of the supply. Around Spring Pond numerous small cottages had been located, and there were evidences that the pollution of the water would rapidly increase unless precautionary measures were taken. Application was accordingly made to the State Board of Health for the establishment of sanitary regulations governing the watershed, and, in addition, land was purchased for a depth of 200 feet from the shore line, thus requiring the removal of all cottages to a considerable distance from the pond. The opportunity to invoke the powers of the Board of Health in the protection of watersheds, by the establishment of definite regulations, is believed to be one of the most valuable provisions in the sanitary laws of the state. While the final results depend on adequate supervision and inspection, these rules focus attention on the necessity for taking particular care in the case ot such watersheds as those from which the Peabody supply is drawn.

Before entering upon a description of the pumping plant, it may be well to briefly consider the records of consumption during the past ten years in Peabody. These are most abnormal in the relation of manufacturing and domestic use, and are of interest

in indicating how rapid may be the increase in the demand for water in a town depending on one particular industry which is, for the time, enjoying unusual prosperity. Tanneries and glue works constitute the local industry and use large quantities of water. In addition to the amount drawn from the town supply — 879 000 gallons per day — probably as much more is obtained from private sources.

The following table shows the water consumed each year in the pumping district since 1895:

TABLE No. 1.

Year.	Gallons Pumped.
1895	330 050 880
1896	339 682 860
1897	340 535 737
1898	353 418 735
1899	415 644 841
1900	377 248 159
1901	411 283 296
1902	456 849 304
1903	544 332 291
1904	611 195 167
1905	639 508 600
1906	691 527 606

From 1895 to 1906 the water consumption increased two hundred per cent., while the population increased by twenty-five per cent. The manufacturing consumption during this period increased two hundred and fifty per cent. The per capita consumption in 1895 was 87 gallons; in 1906 it was 145 gallons. The manufacturing consumption in 1901 was 32 gallons per capita; in 1906, 67 gallons.

The following table shows the increase in manufacturing consumption, domestic and public consumption and leakage since 1901:

TABLE No. 2.

Year.	Total Average Consumption. Gallons per Day.	Manufacturing Use as Measured by Meters. Gallons per Day.	Domestic and Public Use and Leakage. Gallons per Day.
1901	1 200 000	354 000	846 000
1902	1 315 000	439 000	876 000
1903	1 520 000	620 000	900 000
1904	1 800 000	694 000	1 106 000
1905	1 750 000	736 000	1 014 000
1906	1 895 000	879 000	1 016 000

The increase in the column under domestic and public consumption and leakage in 1904 was due to increased leakage from the effect of the higher pressure from the new system.

The Sunday and week-day consumption in 1906 is estimated as follows:

Sunday.	6 A.M. to 6 P.M. =	565,000	gallons per day
	6 P.M. to 6 A.M. =	425 000	" " "
Week day.	6 A.M. to 6 P.M. =	1 510 000	" " "
	6 P.M. to 6 A.M. =	530 000	" " "

The consumption in 1906 may be divided as follows: For manufacturing uses, 67 gallons per capita; for domestic and public uses, 35 gallons per capita; and unaccounted for, including leakage, under-registration of meters, etc., 43 gallons per capita.

The consumption between the years 1900 and 1905 increased 41 per cent., and in the latter year it became apparent that no time should be lost in obtaining an additional source of supply. The town had already obtained the right to the waters of Suntaug Lake, and the utilization of this source was accordingly recommended, construction being begun in the summer of 1905. This lake is situated at a higher level than either Spring or Brown's ponds and the addition of its waters to the old source of supply by gravity was, therefore, possible. The pipe line consisted of 20-inch and 24-inch pipe, laid in trench of ordinary depth for a distance of 15 400 feet, up to the point where the ridge surrounding Suntaug Lake was encountered, the surface of which stands some forty feet above the hydraulic grade line of a gravity conduit. Through this ridge it was accordingly necessary to tunnel. This section of the work, 1 600 feet in length, proved most difficult, and the time necessary for its completion considerably greater than esti-

mated, water not being run through the tunnel until July 1, 1906. In the meantime the abnormal increase in consumption had continued, and during the winter of 1905–1906 the condition of the ponds provided a good object lesson that from a given water-shed and storage capacity only so much and no more water can be obtained. The records which have been kept between the years 1903 and 1906 indicated that the Sudbury records were closely applicable to the Peabody conditions.

Below Spring Pond an intake reservoir of 25 000 000 gallons effective capacity extends northerly for a distance of 3 000 feet, and at its lower end the new pumping station was located. This reservoir constitutes the collecting point of all the different sources of supply, and if in the future filtration should be required it will prove a favorable location for the necessary plant, and the pumping station will be in the right position for the handling of purified water.

From the reservoir a 24-inch pipe was laid to a concrete pump well underneath the station. Double screens of standard design, with catch baskets attached to the bottom section, were located in a screen-well also under the station.

The pumping station is a brick structure with concrete foundations and includes coal-shed, boiler-room, machine shop, engine-room, and office. Emphasis was laid on good head room below the engine-room floor in order to make all piping and auxiliaries easily accesssible.

The pumping plant consists of two 100-horse-power Stirling boilers and a 5 000 000-gallon triple-expansion duplex Worthington pump with high-duty attachment.

The boilers are standard Stirling construction with three banks of tubes connecting the steam drums with the mud drum and a Niclausse superheater suspended between the middle and rear banks of tubes. The boilers contain 990 square feet of heating surface and 28 square feet of grate surface and are designed for 160 pounds working pressure.

The superheater is planned to superheat the steam 100 degrees above the temperature due to a pressure of 150 pounds. It is practically the same as a Niclausse boiler element, and is so arranged by dampers operated from outside the setting that the

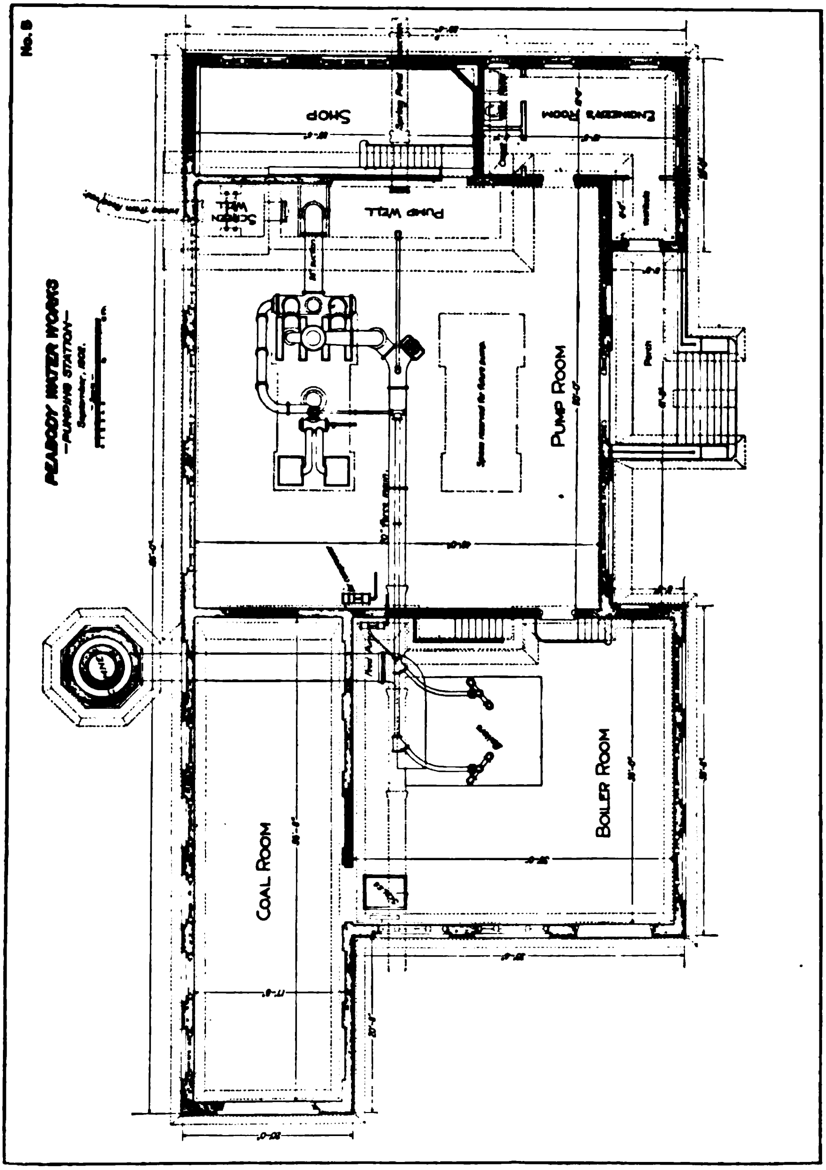

FIG. 1. PLAN OF PUMPING STATION.

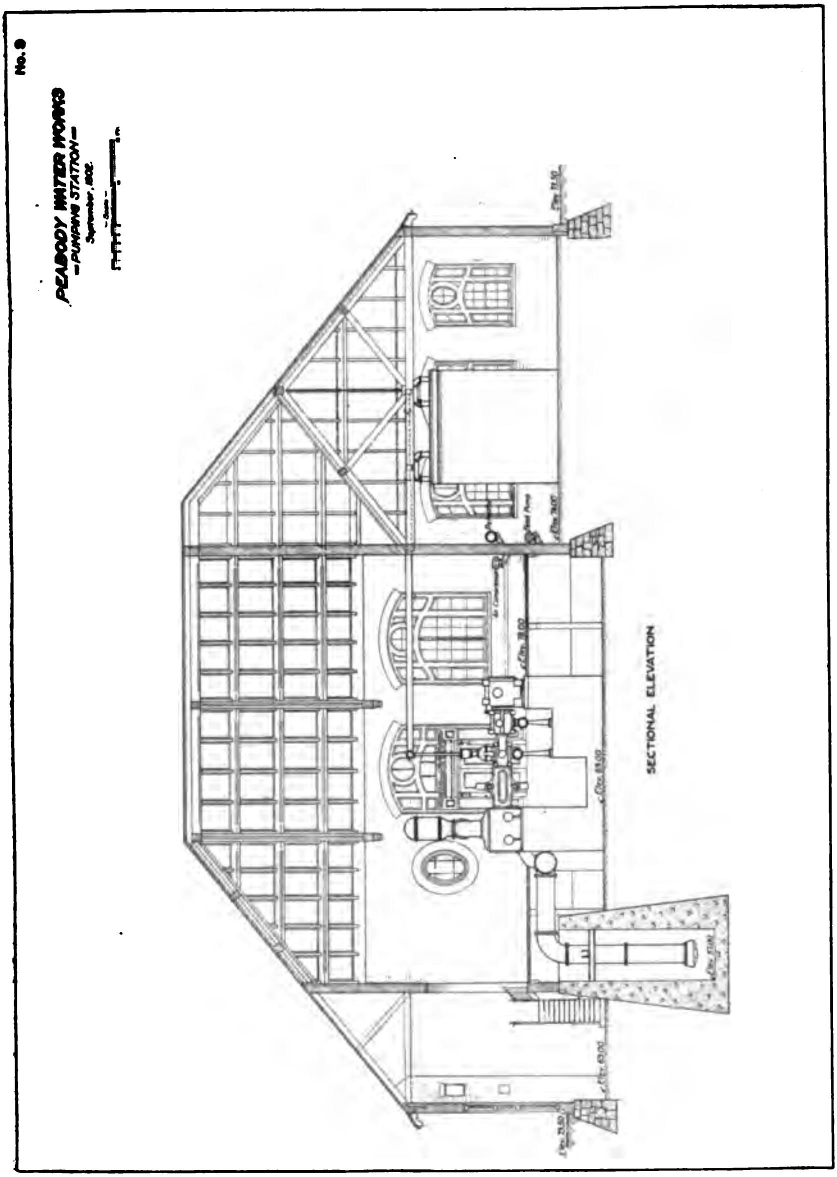

FIG. 2. LONGITUDINAL SECTION OF PUMPING STATION.

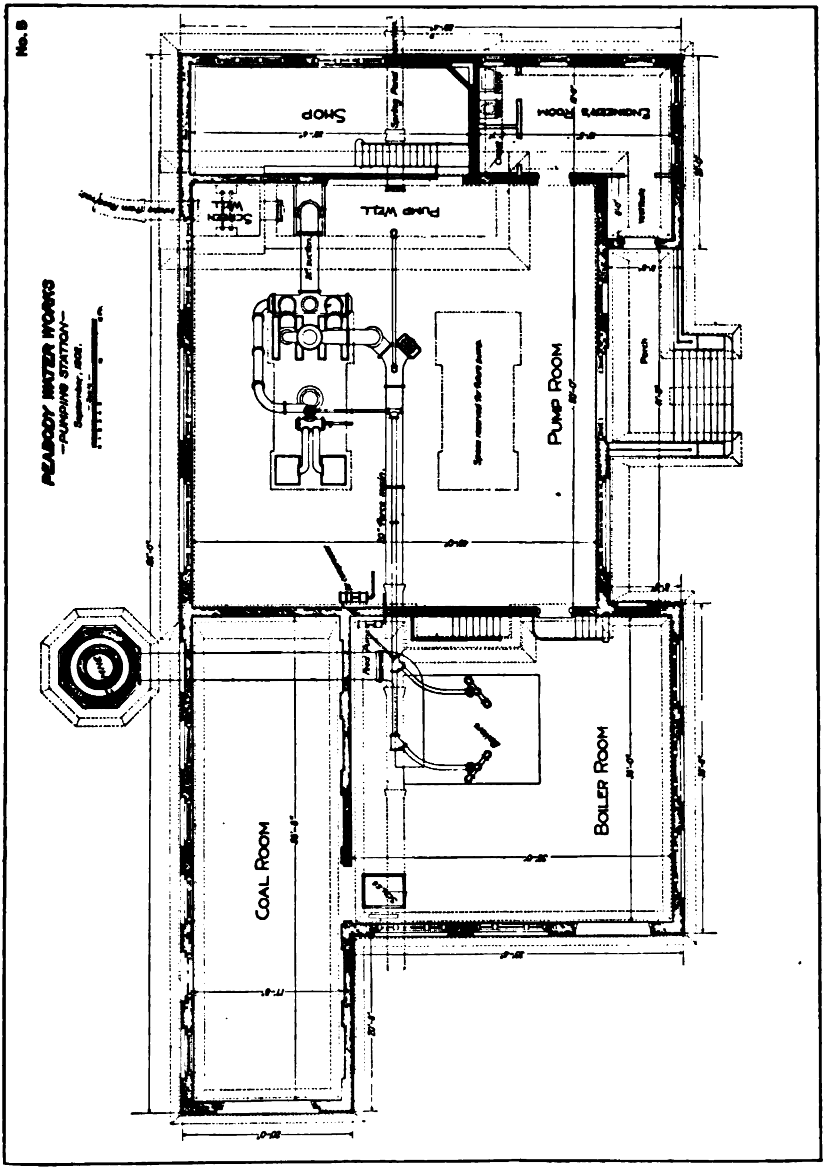

FIG. 1. PLAN OF PUMPING STATION.

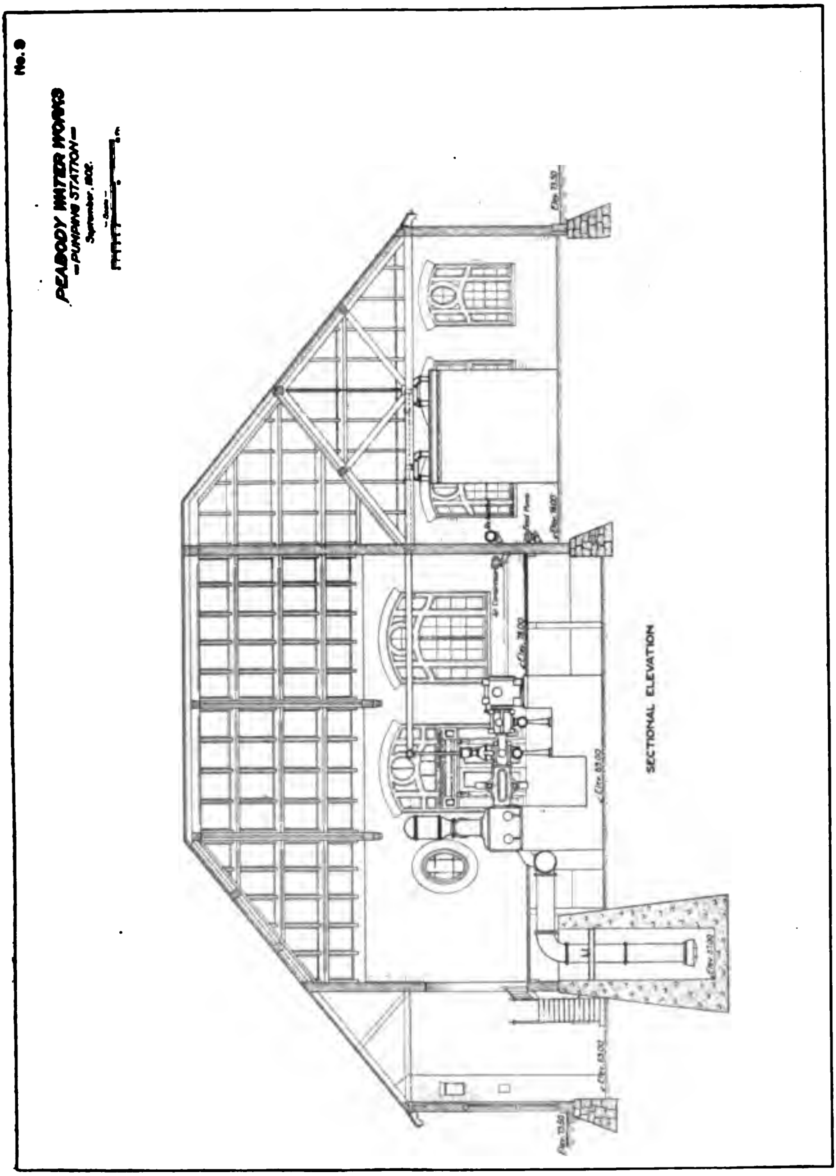

FIG. 2. LONGITUDINAL SECTION OF PUMPING STATION.

gases can be by-passed around the superheater and thus the amount of superheat controlled. Owing to the location of the superheater it is practically indestructible and does not require flooding when steam is not circulating through it.

The engine, as already stated, is a triple-expansion Worthington duplex, with high-duty attachment located between the high-pressure and water cylinders. The diameters of the steam cylinders are 12, 20, and 34 inches, and the nominal stroke 24 inches. The water plungers are 18 inches in diameter, and the average pressure pumped against is 165 feet.

Reheaters are placed between the high and intermediate cylinders and between the intermediate and low-pressure cylinders. The steam cylinders are jacketed with steam at boiler pressure, which also serves to heat the tubes of the reheaters between cylinders. The condensation from this jacket space is collected below in a tank having a ball float which controls the steam supply of a 3 × 2 × 2-inch pump, which takes the water of condensation from the tank and returns it to the boiler.

In the exhaust line between the low-pressure cylinder and the surface condenser is a closed heater having 30 square feet of heating surface. For boiler feed, water is forced through this heater by the delivery line pressure to a 4½ × 2¾ × 4-inch boiler feed pump, at a temperature slightly below the temperature of the main engine exhaust. The feed pump then forces it through a 15-square-foot closed heater which is heated by the exhaust from the feed pump, Westinghouse air compressor, and the jacket pump. The feed is thus put into the boiler at a temperature of approximately 200 degrees.

Located in the suction pipe of the main engine is a surface condenser of 228 square feet surface. A duplex air pump, having 9-inch plungers and 6-inch stroke, driven by the motion of the main engine, takes the water of condensation from the condenser and discharges it to the sewer.

Each cylinder of the engine has four valves operated by the Worthington semi-rotative valve motion, the feature of which is that there are no trips or dash pots, all motion being positive.

An early cut-off is made possible by the use of the high-duty attachment. This well-known Westinghouse device consists of

FIG. 1. FRONT VIEW, PUMPING STATION.

FIG. 2. DRY MASONRY OUTSIDE WALL AND DRAIN.

compensating cylinders and an accumulator, by means of which the surplus energy available at the beginning of the stroke is stored up and liberated at the latter end during the expansion of the steam. The accumulator has an air cylinder 17¾ inches in diameter and a water plunger 4¼ inches in diameter, both of 30-inch stroke. The compensating cylinders have plungers 4⅜ inches in diameter, and the system is supplied by duplex pump having ¾-inch plungers and 4-inch stroke, driven by the motion of the main engine. These pumps receive water from the delivery main or tank that is supplied with clean water from the air pump delivery. A 9½-inch Westinghouse air compressor supplies the air for this system.

No attempt was made to determine the efficiency of the boilers, the contract requiring a duty per 100 pounds of dry Georges Creek or equally good coal burned without allowance for ash, the work being done determined by the water pumped into the reservoir, and the pressure obtained by the reading of a gage on a force main plus the distance from the center of this gage to water in pump well. Under these conditions the contractor guaranteed a duty of 130 000 000 foot-pounds.

The following table gives the principal results of test:

PRINCIPAL RESULTS OF TEST OF PEABODY PUMPING PLANT.

Date of test	June 20, 1904
Duration of test	10 hours
Grate surface	28 square feet
Boiler heating surface	990 square feet
Diameter of chimney	39 inches
Height of chimney	100 feet
Steam pressure in boiler	156 pounds
Draft	0.242 inches
Temperature of fire room	73.4 degrees
Temperature of steam at boiler	423 degrees
Temperature of flue gases	422 degrees
Temperature of feed water	192 degrees
Fuel burned	2 380 pounds
Moisture (per cent.)	0.0094 per cent.
Dry coal consumed	2 357.6 pounds
Steam pressure at throttle	152.9 pounds
Steam temperature at throttle	404 degrees
Superheat	44.33 degrees

Average length of stroke	24.62 inches
Total number of revolutions	22 031
Displacement per revolution	14.303 cubic feet
Total head	163.99 feet
Slip of pump	1.51 per cent.
Rate of pumping per twenty-four hours	5 671 965 gallons
Duty per 100 pounds dry coal	134 607 000 foot-pounds

This relatively high duty for such type of pump working under the above-outlined conditions may be largely attributed to the superheating of the steam.

The test was started and stopped without drawing the fire from under the boilers. Whether ten hours is long enough to nullify the personal equation in the different observations, and particularly in judging the depth of coal on the grate at start and stop, is here, as in all such tests, worthy of consideration. In the writer's opinion, moreover, tests of municipal plants should be made on as practicáble a basis as possible and as nearly in accordance with the actual running conditions as may be arranged. One of the elements not covered by a ten-hour test is the coal used in banking. Recently, in a plant where gas producers are now being installed, the writer called for bids from builders of both steam and gas engines, requiring, on an equal basis, a guarantee of duty determined by a three-days' test, the engine to run 8 hours and fires to be banked 16 hours each day, and the plant being charged with all coal used in banking and all standby losses. Such a test, it is believed, will eliminate to a considerable extent the results of expert firing and the relation of personal error in observation. It also expresses the relative expense of banking in the different types of apparatus.

The station records of the Peabody plant are of interest. The duty, allowing 2 per cent. slip, on basis of total coal burned in 1905, was 77 900 000 foot pounds, and in 1906, 81 500 000 foot-pounds. These figures are relatively 58 and 61 per cent. of the test duty. It is interesting to note that at Attleboro, with a compound crank and fly-wheel engine and a test duty of 119 000 000, the station duty, including banking, is 61.5 per cent. of the test duty, and the experience of the writer is that the working duty will average about 60 per cent. of the duty

obtained in ten-hour tests. The duty at Peabody, without taking into account the coal used in banking, or on the same basis as test, is about 82 per cent. of the test duty. In Attleboro the equivalent figure is 85 per cent. The coal used in banking at Peabody, with the engine running ten hours, is about 28 per cent. of the total coal. At Attleboro, with a seven-hour run of the pumps, exactly the same percentage of the total coal is used in maintaining the fires during the time when the engine is not running.

Few repairs have been necessary, and the engine is a smooth, quiet running piece of mechanism. Such a type of pump, however, requires more attendance, particularly in starting, than a crank and fly-wheel machine, and this is also true of the water tube boilers as compared with horizontal tubular, except where the former are operated in an extensive battery. The limited heat storage in a single water tube boiler demands more constant attention, which is not justified by the quicker steaming capacity in a station where the load is constant. Therefore, while both the test and station duties obtained are good, the labor account is higher than would be necessary in a plant with horizontal tubular boilers and a crank and fly-wheel pump.

Lookout Hill, chosen for the site of the reservoir, is one of the historic spots in the Revolutionary history, of which many are found in the neighborhood of Salem. From its prominence as a vantage point it early gained its name. When, in 1692, John Proctor and his wife, accused and found guilty of witchcraft, were hanged on the neighboring hill to the east, a group of interested spectators probably pushed and crowded for seats on the boulder which is now the special care of one of the historical societies, and to preserve which the reservoir had to be thrown as far to the south as possible. Again, tradition has it that when the *Chesapeake* and *Shannon* met in their historic fight a party of patriots gathered on this eminence and anxiously watched the course of events.

This hill, which was the only one available with the elevation required for a reservoir, in formation was, roughly, an inverted cone of ledge covered with a slight depth of earth. The steep approach rendered the transportation of supplies difficult and expensive and made it necessary to utilize, as far as possible, the materials encountered in the excavation in the construction of the reservoir.

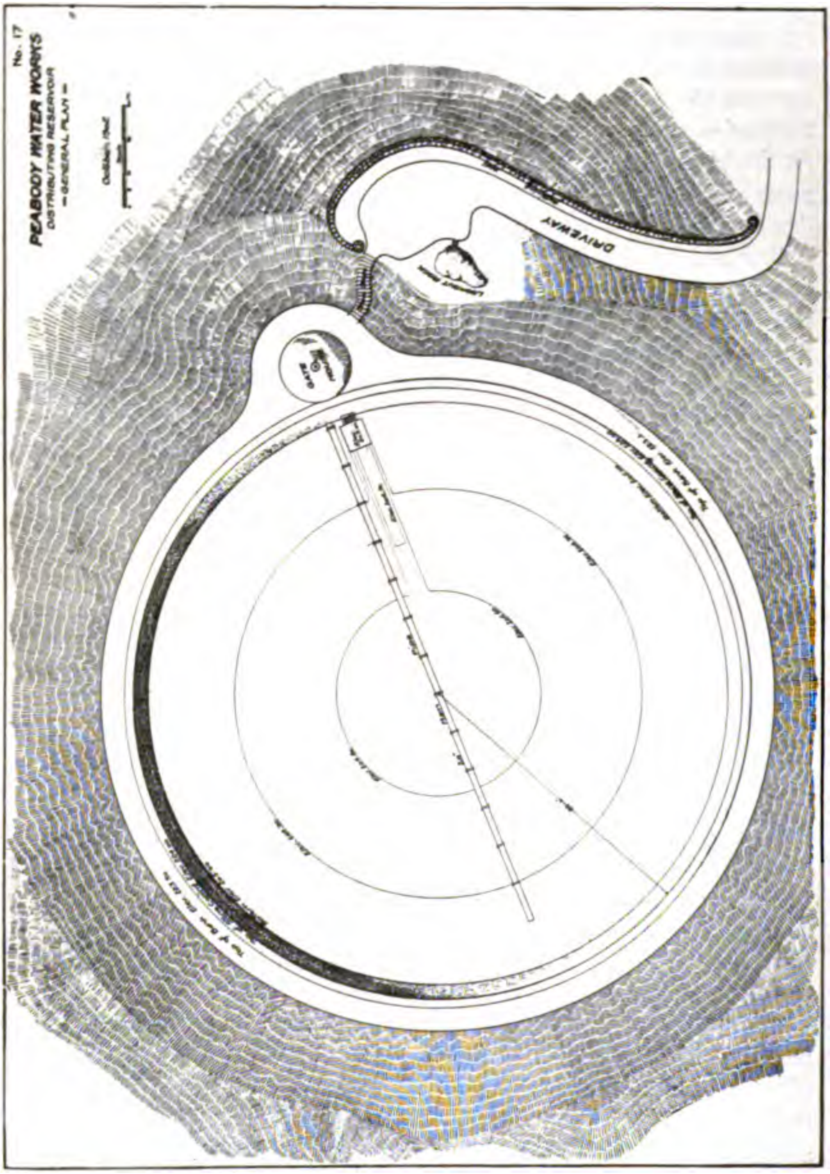

Fig. 3. General Plan of Completed Reservoir.

FIG. 1. EXCAVATION OF LEDGE, AND CONSTRUCTION OF OUTER AND INNER WALLS.

FIG. 2. FINISHED WALL, INLET PIPE, AND OUTLET SCREEN.

The leveling of the cone required the removal of about 5 000 cubic yards of earth and 6 000 cubic yards of rock. The additional earth necessary to back up a masonry lining in the ordinary way could not be economically obtained. At the same time the desirability of leaving the hill in as sightly a condition as possible made it necessary to dispose of the rock excavation without obtrusive spoil banks.

It was accordingly decided to build a dry wall with the excavated rock, laid with interior vertical face on a circle, constructing this wall by merely moving the rock from the place of its excavation by derricks and placing it with only sufficient care to prevent subsequent settlement. Inside of this dry masonry wall it was proposed to build a wall laid with Portland cement mortar, using the stone excavated in the construction of the reservoir, but, with the idea that the stone might not come out in such shape as to permit its use in this way provision was made in the specifications for an alternate plan of lining the dry masonry wall with a wall of Portland cement concrete. In this work, as in all recent work of the writer's, the cement has been furnished by the contractor but paid for separately by the barrel. It was soon found that the nature of the rock, which was a trap and which broke in all manner of shapes and sizes, made impossible the construction of a suitable wall of it, and by arrangement with the contractor it was finally decided to build a thin face wall of rough granite ashlar, obtaining the stone by splitting boulders, which were found in large quantities on the hill near the reservoir, and placing between this granite facing and the dry wall a concrete composed of natural cement and aggregate in the proportion of 1 part cement, 2½ parts sand, and 5 parts crushed stone. The use of the granite facing obtained a structure more pleasing in appearance than would be possible with concrete, did away with the necessity for all form work, and by using natural cement in the backing of concrete, which effected a saving of $1.00 per cubic yard, did not involve much increased cost.

The dry wall, which was placed on the outside to a rough slope, was covered with the earth obtained in the excavation of the reservoir to a depth sufficient to utilize the material available. Thus in this reservoir the construction includes an inner lining, and back of this, for stability, a loose rock filling covered by a coating of earth.

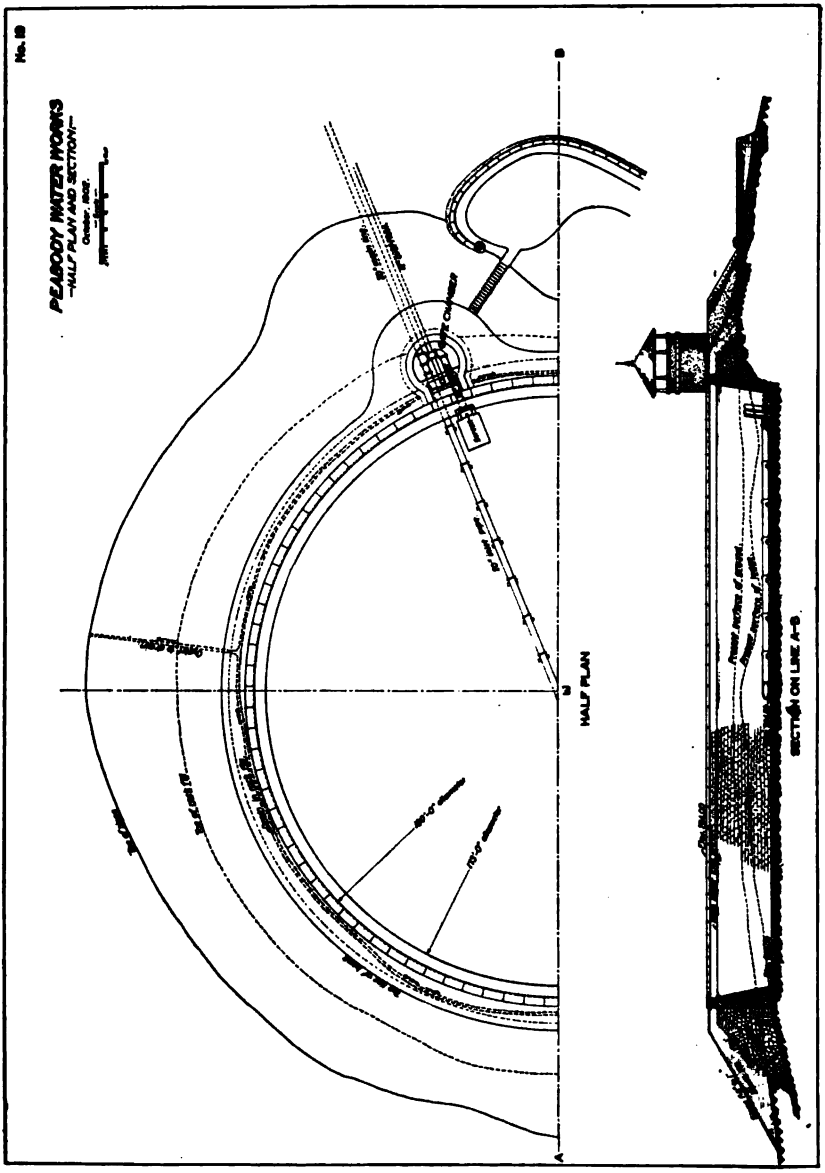

FIG. 4. HALF PLAN AND SECTION OF RESERVOIR.

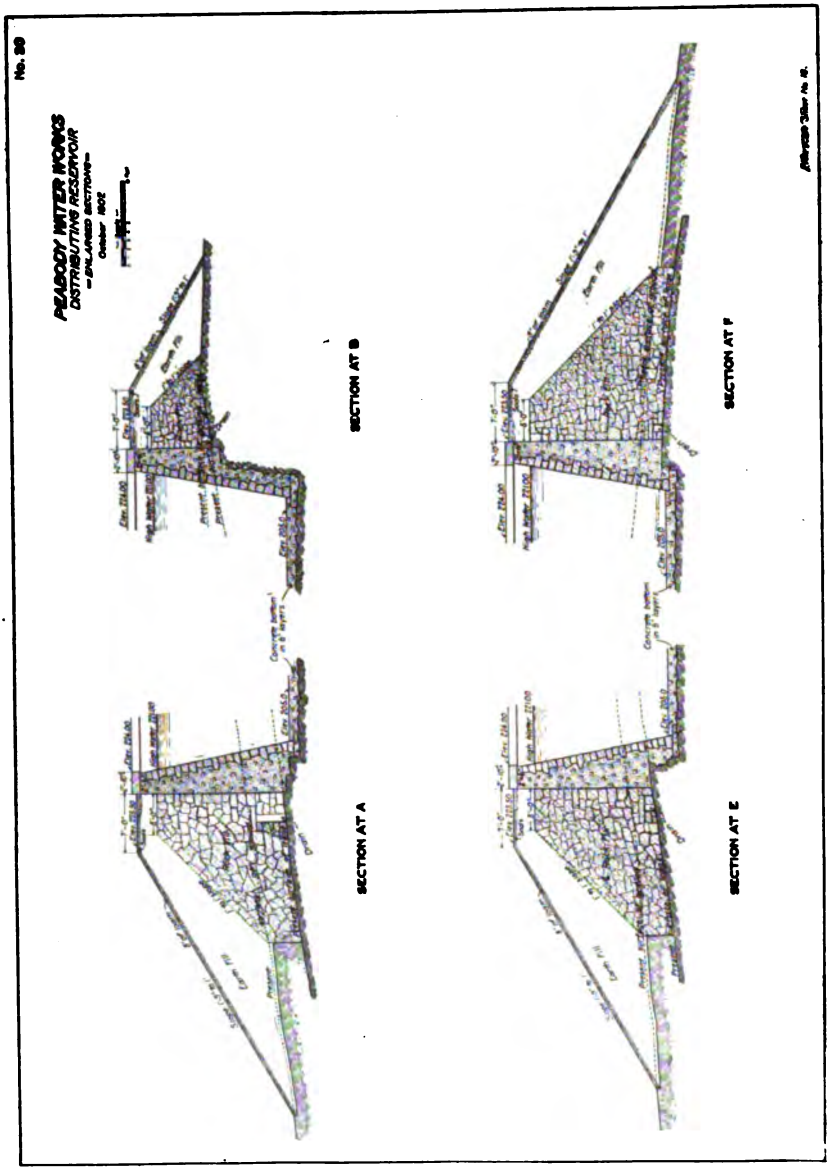

FIG. 5. SECTION OF RESERVOIR WALLS.

Such construction is contrary to the usual method of placing against the lining the most impervious material obtainable. The danger with the scheme adopted lay in the fact that any leakage through the inner wall might be temporarily impounded by the outer layer of earth until it had collected to a point where the earth would be washed away. To prevent this the ledge was stripped as a foundation for the dry wall and on this foundation, and entirely around the reservoir, following the natural contour of the rock, a masonry drain was constructed with its outer wall laid in cement, thus providing a cut-off for all water which might seep through the inner lining. Outlets through the bank to the outside of reservoir were provided at two points and all leakage was led out where it could be seen and measured. Actually this precaution has been of little or no value as the leakage has been practically nothing, one outlet being entirely dry and the other at times showing a dribble which probably comes from a spring encountered in the excavation of the ledge and covered by the concrete floor.

The ledge was very broken and seamy and the bottom of the reservoir was formed of two layers of concrete, the first of natural cement mixed 1: 3: 6, used largely to level up the uneven rock; the upper of Portland cement concrete, mixed 1:2½:5 and troweled to a hard granolithic surface.

The reservoir was enlarged from the original plan to a capacity of about 3 200 000 gallons. The total cost was about $48 000, or 1.5 cents per gallon of capacity. The price paid for rock excavation, which included the building of the dry wall, was $2.25 per cubic yard. The actual cost of drilling was 37 cents per cubic yard; of dynamite, .09 cent per cubic yard; of barring out, breaking up, and removing to the wall, 1.05 cents per cubic yard; and of placing in wall, including construction of inner face, 34 cents per cubic yard. These figures do not include any allowance for rent of machinery.

The 20-inch pipe connecting the distribution system with the reservoir branches in the gate chamber,— one branch, the inlet, extending across the reservoir; and the other, the outlet, just through the wall. By check valves the water is compelled to traverse the reservoir and to pass through screens set over the outlet pipe. At times some sediment is settled out of the water. Gates are also provided in the gate chamber to shut off either

FIG. 1. GATE HOUSE AND LOOKOUT BOULDER.

FIG. 2. RESERVOIR IN SERVICE.

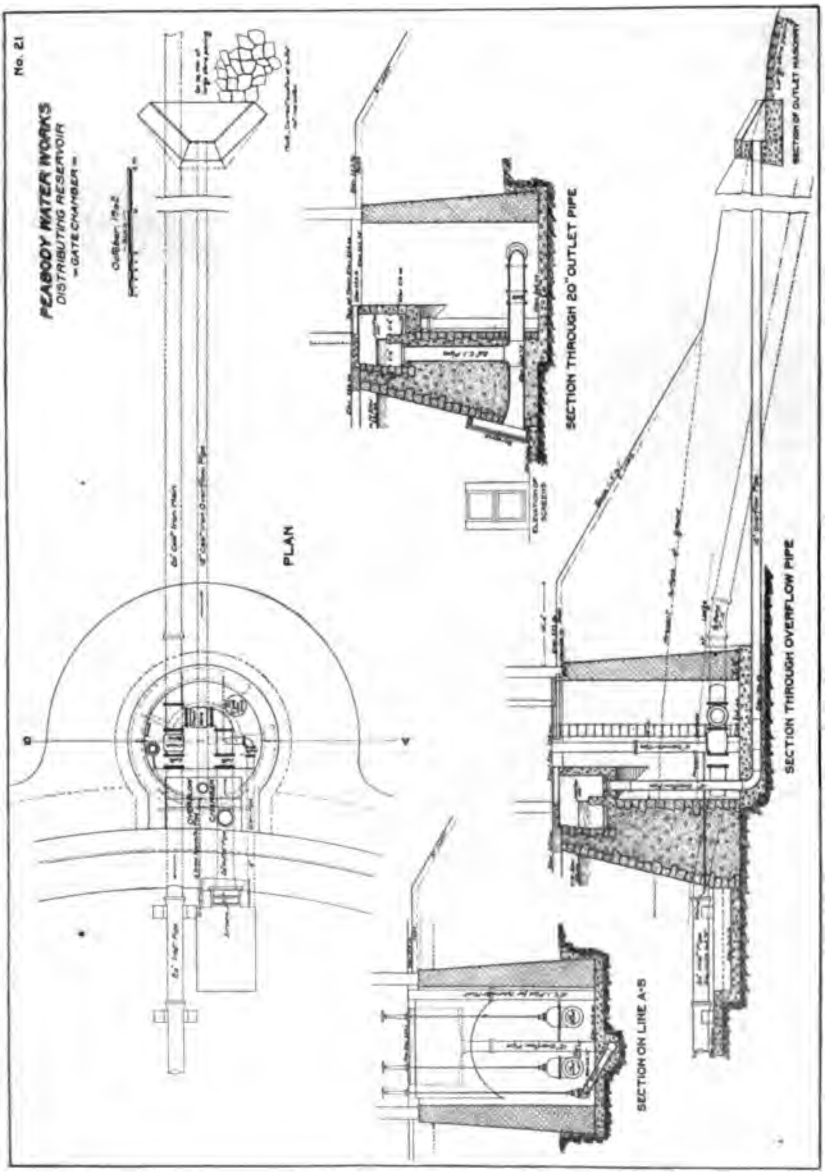

Fig. 6. Details of Gate Chamber.

branch and permit examination of the check valves. A 12-inch pipe makes possible the draining of the reservoir and the blowing off of any accumulated deposit.

The gate chamber is a dry well 13.5 feet in diameter, connected with, but outside the wall of, the reservoir, and containing, besides the various valves, the pipe for the float of the Winslow recording instrument. In this chamber, supported by an arch thrown across on a chord of the circle, is an overflow weir, connected on the reservoir side, by a pipe laid in the wall, with the water in the reservoir, and on the outlet side, by a 12-inch pipe, leading to the blow-off pipe in such a way that at all times there is a free vent, which cannot be closed, for any water which passes the crest of the weir set at the desired maximum water line. Numerous accidents have occurred in reservoirs not provided with overflows, and these even where the water is pumped. The design herein described, while supplying a free outlet, does not weaken the wall nor place the overflow in such position that it will be frozen in winter.

The gates are provided with extension stems and are operated at the level of the ground in a circular masonry gate house constructed over the gate chamber. Above this gate house is an observation gallery open to the public at all times, surmounted by a conical roof covered with red Spanish tiling. The gate house is constructed of stone obtained in the excavation, with seam faces colored by the iron contents. The view from this gate house, which extends over a wide stretch of country to the north and along the shore from Boston Light to Eastern Point at Gloucester, is well worth the trouble of climbing the hill to the reservoir. The town of Peabody owns a considerable amount of the adjoining land which, in its topography and situation, may well form the basis for some future park system. With these conditions in mind, the committee believed that the construction of this gate house and observation gallery was justified, a fact which has been proved by their popularity as an objective point in the recreation wanderings of the citizens of Peabody.

Mr. H. F. Walker was chairman of the special committee under whose authority the work was carried out, and Mr. A. N. Jacobs is superintendent of the water works. The C. E. Trumbull Company were the contractors for the reservoir.

CAST-IRON PIPE SPECIFICATIONS.

BY WILLIAM R. CONARD, BURLINGTON, N. J.

[*Read September 18, 1907.*]

This article would perhaps have been more appropriately called "Some Possibilities of Cast-Iron Pipe Specifications," for it is only intended to show what may be done.

Let us suppose that the various manufacturers of cast-iron pipe have been thoroughly canvassed for the dimensions of their various pipe patterns and it is found, for example, that nearly if not quite all of them have a size of fixtures that will make a pipe of dimensions that coincide exactly or very closely with those shown in the present New England Water Works Standard Specifications for Class "F," which we will say is for a pressure head of 300 feet. This we will consider is about the maximum head that will for ordinary water service be used.

Again, taking these dimensions, we find that for a given class of pipe we have nominal inside diameters of 6 inches, 8 inches, 12 inches, 16 inches, etc. The nominal diameter being also the actual diameter for the heaviest class, it gives the full carrying capacity of that size of pipe. We now wish to provide for a lighter class of pipe for a less head; we still maintain the outside dimensions of bell and body and same bell opening, and increase the internal diameter of the barrel, resulting in less weight of iron in the pipe, and a slightly increased carrying capacity, — this of course being more noticeable on the pipe of larger diameters, due to their heavier walls.

The thickness is progressively reduced in this manner until the lightest class of pipe is reached, and the maximum internal diameter is given. By doing this, one standard outside diameter is maintained for all classes of a given nominal inside diameter, and a standard outside diameter adopted for which the foundries already have fixtures on hand, and their objection of having to make new fixtures and multiplicity of patterns is met.

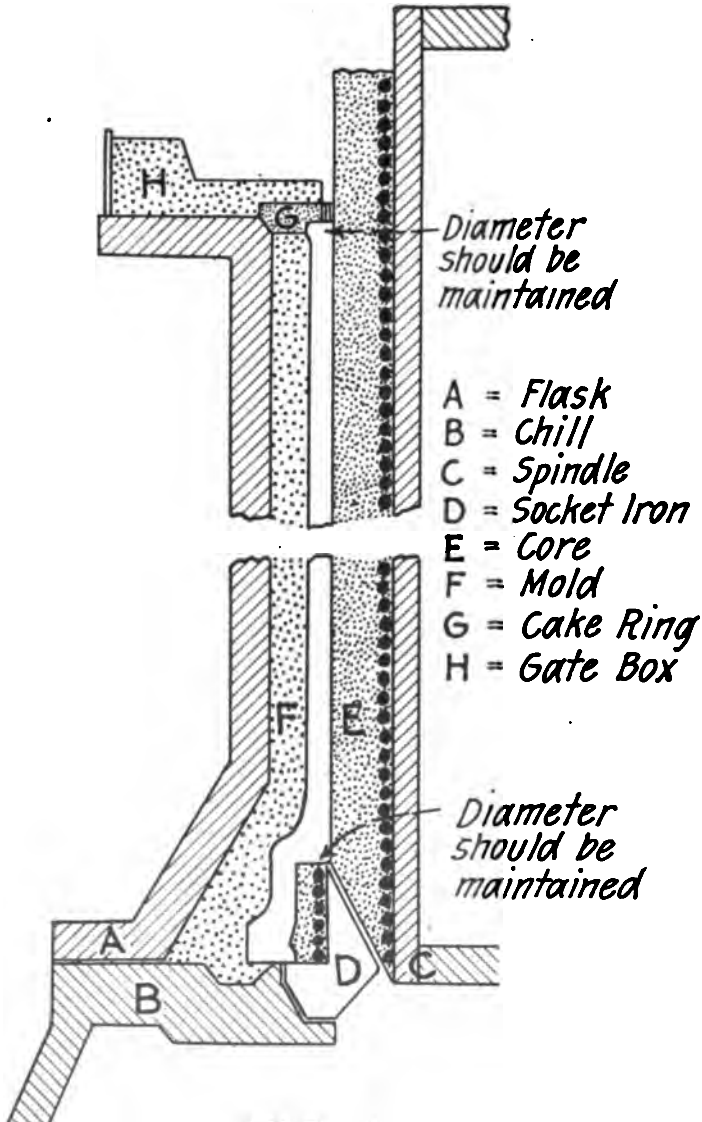
H
G
Diameter should be maintained
A = Flask
B = Chill
C = Spindle
D = Socket Iron
E = Core
F = Mold
G = Cake Ring
H = Gate Box
F
E
Diameter should be maintained
A
B
D
C

FIG. 1

But the foundries' contention of a multiplicity of various fixtures is not altogether met yet, for just as soon as there is a departure from a fixed diameter for that part of the core which forms the extreme end of the barrel of the pipe (the end next the socket and the end forming the spigot), it necessitates a change in fixtures, and is therefore undesirable. (See Fig. 1.)

Under present methods of pipe manufacture, — and our best pipe makers have discovered no other, — it would be impossible to make pipe of various internal diameters and with straight inside lines (see Fig. 2) without multiplying the fixtures quite rapidly, but these can be very materially reduced; in fact, the reduction would then involve only a variety of core bars, and in the case

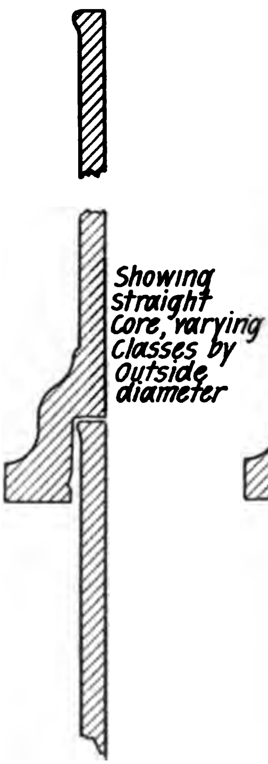

FIG. 2

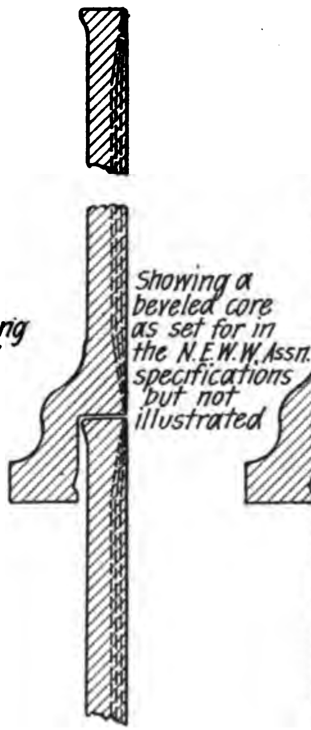

FIG. 3

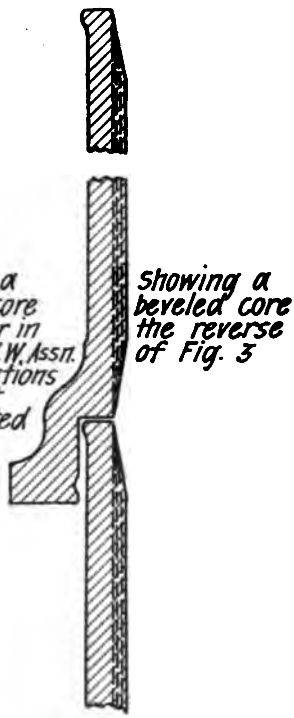

FIG. 4

of the larger diameters of pipe, possibly two sets of core bars or spindles would cover the variety of classes, thus:

By maintaining a set diameter at the ends of the core, and beveling the core for a distance from the ends, either toward the center from the lightest class to the heaviest, the heaviest class to be straight inside (see Fig. 3), or reverse this bevel so that the lightest pipe is straight inside, and as the weight increases the bevel increases (see Fig. 4). Your present specifications make provision for the beveling of the cores as shown in Fig. 3, but it is not illustrated in any way, and is, I believe, not altogether understood.

There has been, almost ever since Standard Pipe Specifications have been discussed by any of the associations that have to do with their use, the question of whether it is possible to obtain one outside diameter for all classes of pipe of a given size; and offhand, except on a few of the smaller sizes where the extremes of variation as between the heaviest and the lightest pipe is a matter of only a few hundredths of an inch, I should say, no, unless some method of beveling the cores is resorted to. The question resolves itself to this: to have a uniform outside diameter for all classes of a given size is desirable, as it will enable any purchaser to order from the foundry any size and number of classes with the assurance that he will receive pipe that will all go together, and will enable the manufacturer to make up for stock pipe that will always go together with other pipe from his own or other manufactories, — he classifying them by weight merely in his stock yard.

On the other hand, it is well understood that in the matter of friction, etc., it is desirable to have the interior surfaces of the pipe as nearly straight and smooth as it is possible to get, and that to have them beveled would be a deviation from this principle. The question is, Which idea has the greatest advantage? There is another matter that would have to be considered, too, and that is, that for entirely new plants, a uniform outside diameter works out all right, and would continue to do so; but would a 12-inch pipe of, say, 13$\frac{3}{8}$-inch outside diameter work in on an extension or replacement in existing lines that might have been made up of light pipe on a base of 12 inches only plus the thickness of wall, say, $\frac{1}{2}$ an inch, making the outside diameter of only 13 inches and

possibly the bell opening $13\frac{3}{4}$ inches? I am inclined to believe that if there was a thorough determination to adapt themselves to it, the management of existing works could and would readily find that conditions would not be as bad in such an incident as at first glance it might seem.

Relative to that portion of specifications which would be text, rather than a table of dimensions, I would note the following: Up to the time the New England Specifications were drawn the usual custom of those purchasers accepting any pipe cut and banded had been to allow 6 per cent. of any given size ordered to be so cut and banded. In compliance with an urgent request from the manufacturers, this was increased to 12 per cent. for 12-inch pipe and larger, and none for sizes less than 12 inches. The result has been in many instances a percentage of bad spigots greatly in excess of 12 per cent., and it has seemed that this allowance should be reduced, so as to try and avoid at least the intimation from some quarters that a premium has been placed on careless workmanship. Another matter is the proneness of the foundry to turn pipe out of the flasks while too hot; and the specifications should be so worded that the manufacturer suffers the penalty of losing the pipe if this is done in any instance, for while it may not be apparent in the pipe at the time, there will result an inequality of the strain on the molecules of iron, which makes the pipe a dangerous one and liable to burst at any time, even after passing all of the tests.

Further, at most of the foundries the life of the inspector for the purchaser is rather a strenuous one, and one of the requirements that might well be inserted would be one requiring the manufacturer to turn out all the pipe being made for any particular purchaser so that they are not mixed with other pipe for other parties, and also to clean, coat, weigh, prove, and pile or ship one day's cast before putting any of a subsequent day's cast through. This would be a decided relief to an inspector, and would enable him to report his work promptly to his employers, and eventually the foundries would, I believe, find it work to their advantage.

DISCUSSION.

Mr. T. H. McKenzie.* Mr. President, I should like to inquire the opinion of the gentleman as to whether first-class foundries do not turn out pretty nearly as good pipe without inspection as they do with inspection? That is, won't it stand the pressure just as well, stand all tests the same, whether it is made under contract or not, — a pressure, we will say, of 300 pounds to the square inch? I shouldn't think it would be for the interest of the manufacturer to turn out defective pipe, whether an inspector is employed or not.

Mr. Conard. Mr. President, I wouldn't be doing myself justice if I were to say that it wasn't an advantage to have your pipe inspected.

Mr. McKenzie. I have bought them inspected and without inspection, and I never could see much difference.

Mr. Conard. Pipe is usually made with a hole in the end and round outside, and water goes through. If one is satisfied to accept them in that condition, all well and good.

Mr. Walter H. Richards.† Mr. President, I recently had occasion to let a contract for cast-iron pipe. A combination of pipe manufacturers offered to furnish it to me, if they could furnish their own inspector and their own specifications. In other words, I could go without it or I could get it somewhere else, which I did.

The manufacturers are willing and anxious to write the specification, furnish the inspector, tell you how thick you want the pipe, and in fact do all the head work. It does seem to me that the party who purchases and pays for the pipe should have something to say about it, and this is best accomplished by having a specification and a good inspector at the foundry. The inspector should see the pipe before it is coated because it is impossible to detect a defect in casting after the coating is applied.

President Whitney. It seems to me that Mr. McKenzie's suggestion is almost too much of a temptation to the average pipe manufacturer. What do you think, Mr. Wood?

Mr. Wood. I don't quite catch your question.

President Whitney. Mr. McKenzie thinks inspection un-

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* Civil Engineer, Southington, Conn.

† Engineer Water and Sewer Department, New London, Conn.

necessary. It seems to me that is putting almost too much temptation up to the pipe manufacturers.

MR. WALTER WOOD.* I think the proper way to look at the matter of inspection is this: to a pipe manufacturer it is no disadvantage to have inspectors at his works. It is one of the easiest ways of keeping his men in order, because when you complain of your men not doing good work you can say the inspector said so, and you are relieved of any criticism from your labor. So I think any good pipe manufacturer should always be willing to have inspectors at his works, and I think, really, while we are talking on the subject, that this is the greatest use of pipe inspectors. I do not think that an inspector, as a rule, gets better pipe for a purchaser than if the buyer depended on the inspection of the pipe manufacturer which is based on long experience. Any pipe manufacturer aims to make good pipe, and I don't think he knowingly ships out any pipe which is bad. There is no doubt but a great many pipes are laid aside by inspectors which a pipe manufacturer would ship out. There is no question about it. I will tell you a story.

A prominent engineer said, "I have got a bully good inspector. It makes no difference whether pipe is 6 inches or 60 inches in diameter, if a fly lights on it and leaves a speck he finds it and rejects the pipe."

MR. A. A. REIMER.† Perhaps it is too bad to take issue with the last speaker directly, but in East Orange we have had a rather sad experience without inspection, which may be something in the line of help to one of the previous speakers on this question. We have a good many miles of pipe, from 4 inches up to 24 inches, and for some years we demanded no inspection except on our large sizes of pipe. We got all of our pipe from one foundry, and felt, in consequence, that the foundry should at least keep East Orange in good shape when we wanted pipe, but it was our sad experience only two years ago to find that we were getting a poor quality of pipe. It was pipe, as Mr. Conard says, that was round on the end and outside, and it held water for a while, but that was about as near as it came to being real pipe. When I took up the

* Of R. D. Wood & Co., Philadelphia, Pa.
† Superintendent of Water Works, East Orange, N. J.

matter with the foundry and asked why we were treated in such a manner the president begged off, saying that he did not know that such pipe had been sent to us. I informed him that from that time we should employ an inspector. That is how Mr. Conard and I came to an understanding, and since then we have had pipe that is right.

Another point is this: in buying pipe without inspection I believe that all of us pay a big premium. I know we have. I believe that the manufacturer will send out pipe far heavier than we call for or need. Say, for instance, that you call for 6-inch pipe of a class that should weigh, perhaps, 385 pounds per length under the specifications. Your pipe will probably average, without inspection, fully 400 pounds per length, instead of 385, and in a large order that becomes a large item in paying for dead weight that does you no good, if the pipe you have called for will withstand the pressure you know to be sufficient.

I would like to relate an experience which came my way about a year ago. One of our neighboring cities called us up and wanted to get some pipe from us. We were in a position to help out and let them have all they needed. When they came to replace it we were asked if we wished to exchange on the basis of weight. The pipe in question was 6-inch, and we had sent them pipe weighing about 385 pounds per length, New England Water Works Association specifications. We were offered in exchange pipe weighing about 440 pounds per length, average. I wondered how this came about for I knew that no such weight of pipe was needed in that place. Then I recalled a conversation I had had some time before with the neighboring superintendent, in which he assured me that he had no trouble in getting pipe promptly and at a price nearly $4.00 per ton lower than we were paying. When the offer was made to return such heavy pipe, I understood why their price was so low. That place was paying for probably 100 pounds useless weight in each length, and then was getting pipe that had been rejected by others, the seconds and thirds of the foundry. So I believe in inspection.

And now, Mr. President, I wish to speak of one little matter at this time. Last fall at one of the meetings I had occasion to

mention by name a foundry that I criticised for failing to accept the New England Water Works Association specifications. At this time I wish to say, to be fair, that the United States Cast-Iron Pipe and Foundry Company, which is the one I criticised last fall for refusing to make pipe except on their own specifications, has very willingly complied with our specifications on the last few orders that we have placed. I think it is only due to them, inasmuch as I criticised them last year, that I should say that they are entirely fair and willing at the present time.

President Whitney. Is there anything further to be said in regard to Mr. Conard's paper?

Mr. Conard. Mr. President, it is a little unfortunate that all the discussion there has been on the paper has resolved itself down to the question of inspection. That wasn't at all the intention of the paper. It was intended to show you what could be done with cast-iron pipe *specifications*, and not what an inspector can do. It seems to me if we are going to have any discussion on the question of cast-iron pipe specifications it should be on the specifications themselves.

Mr. McKenzie. Mr. President, I didn't want it understood that I wasn't in favor of inspection. I usually have an inspector myself, but I wanted to bring up a little discussion on the subject. As a rule you can inspect pipe on arrival and delivery, and with such inspection foundries are not liable to ship defective pipe.

President Whitney. I think you did bring out a little discussion, Mr. McKenzie. Perhaps it would be interesting to hear from a manufacturer on this subject, — as to changes in the pattern. Mr. Wood, what do you think of Mr. Conard's idea as to changes of patterns?

Mr. Wood. That question of the interior changing of the core or the outside diameter of the pipe was very thoroughly gone over between the committees of manufacturers and the New England engineers when the New England specifications were drawn up, and I think what is in the New England specifications on that point is as fair a conclusion as could be found. I don't think the manufacturers have any objection to the way it works out practically, although the engineers asked them to do something which

they felt would be somewhat of a burden. So I think the New England specifications on the inside and outside diameters is a fair agreement. I don't think either side has any wish to bring them up and criticise them.

There is one question which I do not quite understand the drift of in Mr. Conard's paper, — that is, the cutting off of the upper end of the pipe. There is no question but that it improves the casting — any casting — to have its upper end cut off. Any casting, even if it is apparently sound, has some slight defect which it is better to have cut off. I said so once before in one of the New England meetings, and I have been quite struck with some of the work we have been doing in this line. We have been trying cutting off the end of some of our pipe, and we have had people come back and say, "We prefer that kind of pipe; send us some more." It gives a cleaner, better end to the pipe, and specifications that provide for every pipe to be cut off will be a step in a better direction. It will give a higher grade of work altogether, give you better castings, and be more satisfactory in every way for yourselves and for the manufacturers, I think; the aim of all the manufacturers is to get good work, and cutting off the end of every pipe, 100 per cent., will give you very much better work than cutting the ends off from only 5 per cent. to 12 per cent.

Mr. Conard. Mr. President, I don't know as there is anything special to be said in reply to Mr. Wood's suggestion. The specifications now only call for an allowance of 12 per cent. of the pipe cast, and do not provide for any elongation being cast for cutting off. If the specifications were to be so arranged to apply to the cutting of 100 per cent. of the pipe, and called for an elongation to be cast on the end of the pipe, to take care of any bad metal there may be in the upper end, I agree with Mr. Wood that it can probably be accomplished, just so long as the workmen in the foundry will see to it that they maintain that good standard of workmanship. I don't for a moment want to be understood as criticising the manufacturers or the management of the pipe manufactories, because I think without exception they all want to furnish good work and all want to furnish the best workmanship possible, but there are often times when they can't keep track of all contingencies.

Mr. Wood. Perhaps I might say a word more. Of course, if every pipe is to be cut off there must be provision in the casting for cutting it off, and if the specifications are really brought up to the highest grade they will provide for five or six inches to be cut off of every casting; so you will always have a solid bead.

EXPERIMENTS ON VARIOUS TYPES OF FIRE HYDRANTS.*

BY CHARLES L. NEWCOMB, MECHANICAL ENGINEER, HOLYOKE, MASS.

[Presented by Robert E. Newcomb.]

(Read November 13, 1907.)

The fire hydrant, called in many places a fire plug, is an important part of the fire apparatus which our cities and towns are providing to guard against the fire hazard. The importance of this apparatus is at once seen when we remember that on the average each year over one hundred million dollars' worth of property is destroyed by fire in the United States.

The object of these tests was a complete investigation of the fire hydrants now commonly used, and the work was divided into the following classes:

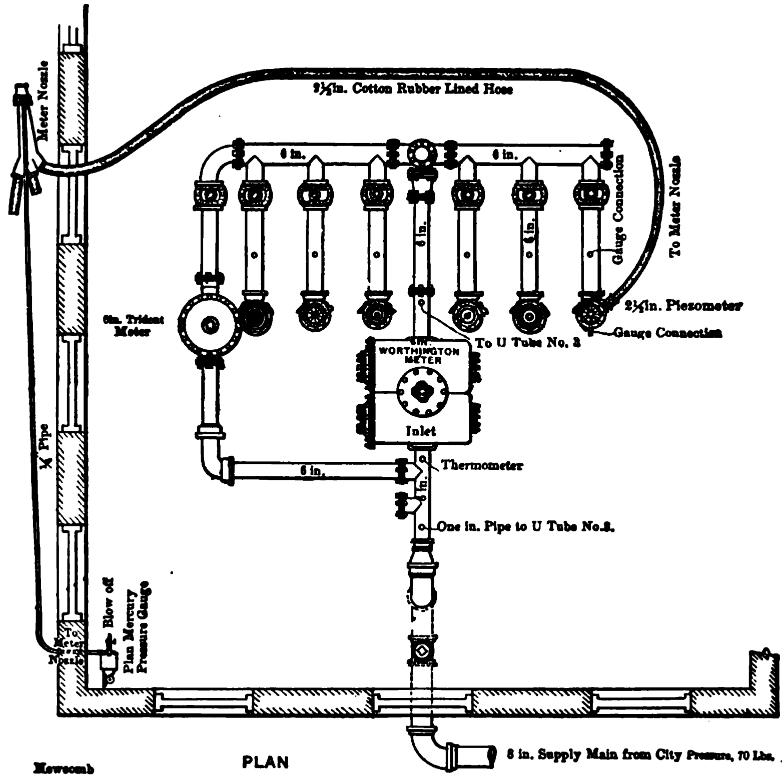
1. The loss of pressure due to the friction of water in the hydrant, the total loss being subdivided into barrel loss and nozzle loss.
2. The discharging capacity of open hydrant butts at different pressures.
3. The water-hammer caused by quickly closing the main gate.
4. General features of construction, certainty of action, strength, durability, etc.

Some interesting data were also obtained on two 6-inch meters which were used in the tests.

A few tests on several different hydrants were made in 1886 by Prof. Selim H. Peabody, of the University of Illinois. The results of these were not entirely satisfactory. Mr. John R. Freeman, in his "Hydraulics of Fire Streams,"† gives a table the discharge of one open butt of a four-way independent gate hydrant at various pressures and some percentage corrections when using the table for other types of hydrants. Beyond

* Somewhat abridged from a paper presented to the American Society of Mechanical Engineers in 1899. (Trans. A. S. M. E., Vol. XX.) Published by permission.

† "Experiments Relating to Hydraulics of Fire Streams," Transactions, American Society of Civil Engineers, Vol. XXI, Table B – No. 3.



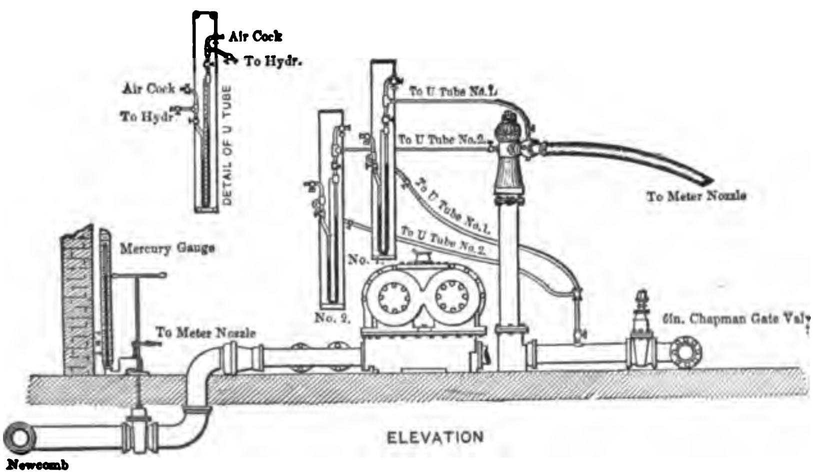


FIG. 1. PLAN AND ELEVATION OF PIPING, SHOWING THE ARRANGEMENT FOR TESTING OF FIRE HYDRANTS, HOLYOKE, MASS., NOVEMBER, 1897.

these tests the writer has been unable to find anything of importance, though diligent inquiry was made. In the experiments here described it was possible to test a large number of hydrants under widely varying conditions, and the aim has been to bring out results which would be of value to hydraulic engineers and hydrant manufacturers.

The tests were made for the Water Department of the city of Holyoke, Mass., at the request of the water commissioners. They were carried on in the basement of the water-works shop, commencing in November, 1897, and ending in June, 1898, with an intermission of several months. The full facilities of the Water Department were at all times available, thus making it possible to go into the investigation with much thoroughness.

The writer is indebted to Mr. John R. Freeman, of the Factory Mutual Fire Insurance Companies, for valuable suggestions from his large experience in testing work, and for the general coöperation of the Inspection Department of Factory Mutuals. Mr. Frank L. Pierce and Mr. E. V. French, of this department, made frequent visits to the testing-room during the experiments and gave much help in planning the scope of the tests and the arrangement and handling of apparatus. The testing work done in 1897 and in January, 1898, was under the immediate charge of Mr. Ezra E. Clark, of Springfield, Mass. The work done in June, 1898, was under the immediate charge of Mr. A. L. Kendall, of the Factory Mutuals. Messrs. French, Clark, and Kendall have also aided in carrying on the computations and in getting the report in shape for publication.

The hydrants were in part bought from the manufacturers and in part loaned by them. In all cases it was fully explained that the hydrants were to be used in extensive tests and that the usual commercial article was desired. The cheerful cooperation of the manufacturers was of material help throughout the experiments.

The mercury gages and the meter nozzle were loaned by the inspection department of the Factory Mutuals. The Trident meter was loaned through the kindness of the Neptune Meter Company. The Worthington meter was purchased specially for the work.

FIG 1. INTERIOR OF TESTING-ROOM.

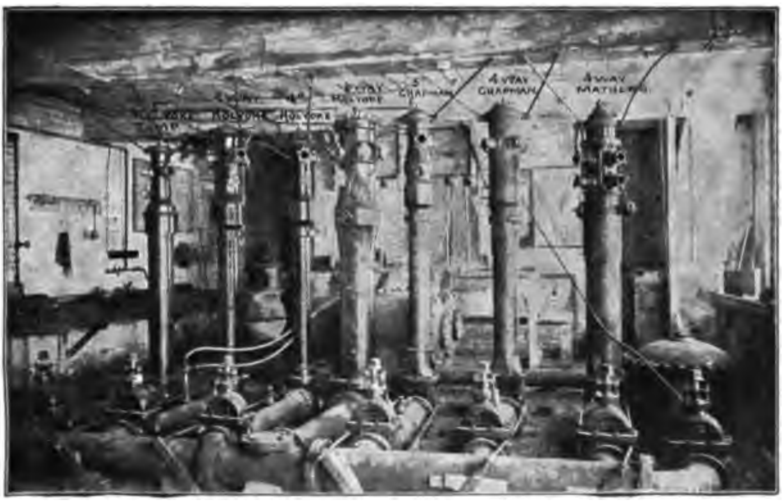


FIG. 2. INTERIOR OF TESTING-ROOM.

ARRANGEMENT OF APPARATUS.

The water for the tests was drawn from the city mains, an 8-inch pipe being laid into the basement for this work. The city is supplied by gravity from reservoirs, and the pressure was generally quite steady. The mains were of such size that all water needed could be obtained at good pressure. Fig. 1 shows the general arrangement of apparatus. The 8-inch main was provided with a gate just inside the building. It then connected with a 6-inch Worthington meter. A short length of pipe connected the meter to a manifold with six outlets. To each outlet was attached a 6-inch gate, and each hydrant connected with a gate by a short length of 6-inch pipe. Plates I and II, made from photographs, show the general appearance of the apparatus.

Piezometers. About 2 feet from the inlet of the hydrant a hole for ¾-inch pipe was drilled in the cast-iron pipe and tapped. Into this hole a short nipple with a stop-cock was screwed, from which connections were taken for the gages. This connection served in place of a regular piezometer and can be relied upon to give sufficiently accurate results, as the velocities were not high and there were several feet of straight pipe back of the hole, so that a uniform condition of flow might be expected. Care was taken to drill the hole at right angles to the pipe and to prevent the gage connection from extending into the pipe. Care was also taken to remove any burr made in drilling. If either of these points had been neglected a false reading would have been the result.

A ¼-inch hole was tapped into the back of the hydrant about on a level with the nozzles, and a connection screwed in with the same care as for the 6-inch pipe. To the 2½-inch hydrant outlets special piezometers, as shown in Fig. 2, were attached. The circular space extended around the piezometer and connected with the interior by four ⅛-inch holes drilled at right angles to the axis of the bore. The pipe leading to the gages was connected to this space between two of the holes. This arrangement materially assists in the accurate determination of the pressure when the velocity is high and the water is likely to be in eddies, as would be

the case at the outlet of a hydrant. At the end of the piezometer a 50-foot line of ordinary 2½-inch cotton, rubber-lined, jacketed fire hose, loaned by the Fire Department, was attached, which conducted the water to a meter nozzle located in the yard. When two outlets were in use two lines of hose were employed, and for the three- or four-way hydrants three and four lines were used. With two lines of hose two piezometers were used and connected together by a short length of ½-inch pipe. The connection for the U-gage was taken from about the middle of this pipe. When using more than two streams only two piezometers were used, it being assumed that the average pressure was fairly well secured in this way without the use of a piezometer on each outlet.

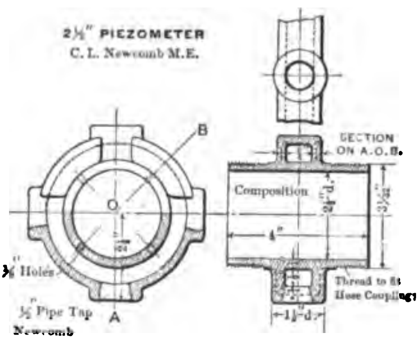


FIG. 2.

Meter Nozzle. The meter nozzle was one designed by Mr. John R. Freeman for accurate water measurement. A cut of it is shown in Fig. 3.* The three-way connection joins a 3¾-inch smooth-bore play pipe, having at its end a 3¾-inch piezometer made on the same principle as the 2½-inch piezometer shown in Fig. 2. To the end of the piezometer nozzles from ½-inch to 2½-inch bore can be screwed. When using four streams an ordinary Siamese connection was screwed to one of the inlets. For the six streams in the tests of the six-way hydrant, the fifth and sixth lines were run separately and each provided with an Under-

* A full account of the original tests of this nozzle will be found in the Transactions, American Society of Civil Engineers, Vol. XXIV.

PLATE II.

FIG. 1. EXTERIOR OF TESTING-ROOM, SHOWING METER NOZZLE IN OPERATION.

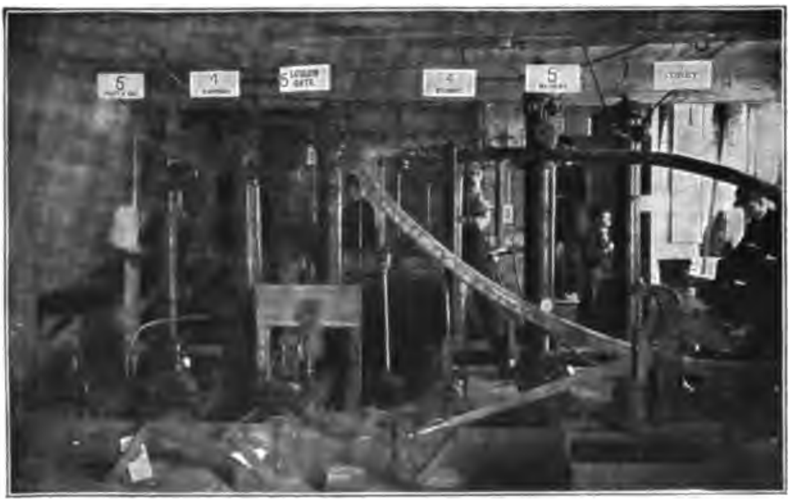
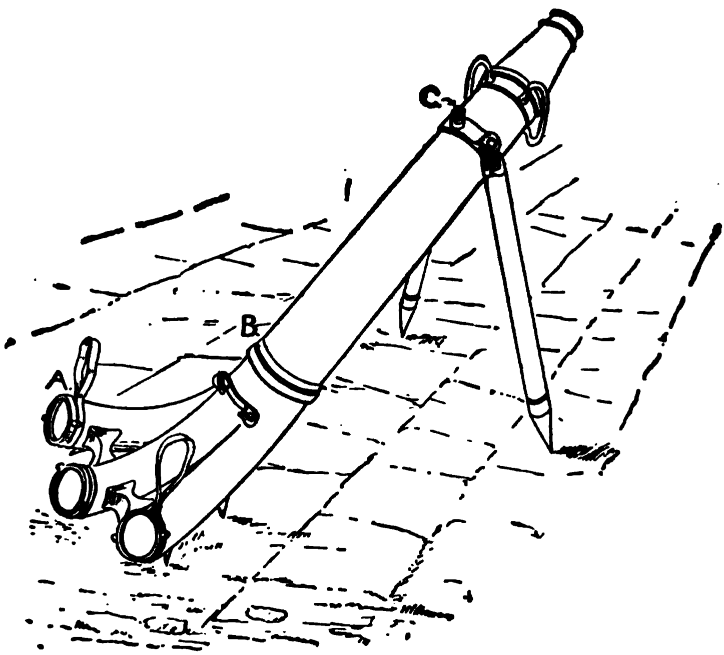


FIG. 2. INTERIOR OF TESTING-ROOM, SHOWING HYDRAULIC TEST PUMP ON RIGHT AND WATER-HAMMER RIG TO LEFT OF CENTER.

writer play pipe. At the base of one play pipe was a 2½-inch piezometer, which was connected to the mercury column and turned on alternately with the meter nozzle.

With the pressure at the nozzle piezometer accurately known the quantity of water can be readily computed. In all the friction loss tests the quantities were determined by the nozzles rather than by the meter. The Worthington meter gave trouble from its pulsations affecting the gages, so that the by-pass connection shown at the left in Fig. 1 was put in and the meter abandoned.



C, Piezometer gage connection.

FIG. 3. METER NOZZLE.

Later the Neptune meter was put into this connection and used for the last part of the open-butt tests.

Gages. The nozzle pressures were measured by a mercury column * with a scale graduated to read pounds and tenths of a

* For the general construction of the mercury column, method of graduating the scale to compensate for lowering of the cistern, weight of mercury, etc., see "Hydraulics of Fire Streams," by J. R. Freeman, Transactions, American Society of Civil Engnieers, Vol. XXI.

pound directly, and to include a connection for the lowering of the surface of the mercury in the cistern. The gage was connected to the nozzle piezometer by ¼-inch iron pipe and rubber tubing, care being taken to have the joints practically tight. The pipe sloped upwards from the nozzle, and a blow-off cock was placed at the highest point so that all air in the connections could be surely blown out. The gage was set up against the rear brick wall of the building, and the tube extended into the second story of the shop through a hole in the floor.

Losses of pressure were measured between the 6-inch inlet and the connection at the top of the hydrant; also between the 6-inch inlet and the 2½-inch piezometer. Thus the first gave the barrel loss and the second the total loss. The difference was then the nozzle loss. These losses were measured directly on a U-tube mercury gage made and connected about as shown in Fig. 1. For this gage a heavy glass tube with an inside diameter of about ¼ inch was bent into the shape of a U with one leg about twice the length of the other. The tube was filled with mercury nearly to the top of the shorter leg. A short length of rubber tube was cemented to the top of each leg. This tube connected the glass to a fitting made up of ordinary ¼-inch pipe and containing stop-cocks and a blow-off cock for air. From these fittings connections of ¼-inch iron pipe or of rubber hose were taken to the points in the hydrants between which the loss was desired. Care was always taken to have the connections slope upward from the hydrant to the air-cocks so that when the cock was opened the swiftly flowing current of water washed out all air in the connections.

These gages gave directly the gross loss of pressure between the two points with which connection was made, this loss being the difference in height between the two columns less a slight correction for a column of water of a height equal to this difference. A measuring stick graduated directly in pounds and tenths of a pound was fitted between the legs of the tube and gave the readings directly in pounds.

Open-butt Tests. In the open-butt tests the water was discharged directly from the 2½-inch hydrant butt. The floor of the test-room was of brick laid in cement with a large drain all

prepared especially for this work, so that the water could be blown out anywhere in the room.

For the tests to and including No. 368 the mercury gage was connected to the 6-inch piezometer at the inlet of the hydrant, and a U-gage connected between this point and the connection on the back of the hydrant. The pressure at the outlets was then the mercury-column reading corrected for elevation less the friction loss through the hydrant, which was given by the U-gage. After test No. 368 the mercury column was connected directly to the nipple at the back of the hydrant barrel opposite the outlets. This gave the pressure directly at the outlets and was better than the first arrangement, as it avoided the errors of the U-gage.

Friction Losses. In all the tests observers were placed at the different gages and took readings simultaneously at the sound of a bell, a warning bell being struck five seconds before the time for the reading. The majority of the tests were of ten minutes' duration, and readings were taken each minute. A few of the tests were of five minutes' duration, and in these half-minute readings were taken.

The following program was adopted for all the friction-loss tests:

Condition.	Size of Meter Nozzle.	Approximate Pressure at Nozzle.	Approximate Gallons per Minute Flowing.
One hose outlet.............	¾ inch	66 pounds	130
,, ,, ...	1⅛ inches	46 ,,	250
,, ,, ...	1¼ ,,	33 ,,	350
,, ,, ...	1¾ ,,	24 ,,	450
,, ,, ...	2 ,,	19 ,,	550
Two hose outlets............	1¼ ,,	65 ,,	375
,, ,, ...	1¾ ,,	30 ,,	500
,, ,, ...	1¾ ,,	45 ,,	625
,, ,, ...	2 ,,	34 ,,	750
,, ,, ...	2½ ,,	17 ,,	850

In all cases after the water was started ample time was allowed before the readings were commenced, to make sure the water had come to a steady condition of flow.

Before or after each series of tests the zero reading of the mercury column was obtained by filling the gage connections with water and holding the end level with the center of the nozzle and then reading the gage.

At the end of a series of tests the averages were quickly computed and checked, and the gross loss in pounds and the gallons per minute discharged for each condition were plotted on cross-section paper and a curve drawn through the points. This gave a constant check on the work and quickly showed up any error. The occasional prompt finding of a discrepancy tended strongly to impress the observers with the need of care in taking readings and handling the apparatus. For this reason, and for the greater ease with which any trouble is located and remedied, and for the chance of studying the results and investigating at once while the apparatus is in place any special feature, this method of carrying the computations along with the work is believed of the greatest benefit to the experimenter. The chance of false readings was carefully guarded against by liberal blowing off of all connections before each test. For a number of hydrants series of tests were repeated to try the accuracy of the work, and it was almost invariably found that the two series agreed well within practical limits.

The question was raised whether the high velocity of water through the 2½-inch hydrant butt might not cause such a contraction of the stream as to affect the readings of the U-tube. Two series of tests were therefore made on one hydrant, one with the 2½-inch piezometer next to the hydrant outlet, which was the usual arrangement, and the other with a piece of 2½-inch pipe about 2 feet long between the hydrant and the piezometer. A special test for the friction loss in this 2½-inch pipe was then made, and, correcting for this loss, the results were found to be practically the same in the one case as the other, showing that the piezometer screwed directly to the hydrant could be relied upon for accurate results.

Computations. The average readings from each test have been copied on data sheets arranged with parallel columns. The main steps of the computations have also been put upon these sheets, thus giving a complete record of the work. The friction loss tests are arranged in alphabetical order according to the names of the hydrants, with all the tests on one make of hydrant grouped. The open-butt tests are in order of test numbers. For a few of the hydrants complete tests were not made for lack of time. The absence of data will show where these omissions occur.

The detailed tables of experimental results are not included with this paper since the Tables I to VI inclusive, and the diagrams, show "the results in brief." For further details reference may be made to Transactions, American Society of Mechanical Engineers, Vol. XX, where the tables are given in full.

Open-butt Tests. The general method of procedure was the same as for the friction tests. The mercury column and the U-gage, in the tests where it was used, were read in the same way and with the same care as in the friction-loss tests. The quantity of water was obtained from the meters, the Worthington meter being used in all of the earlier tests, the Neptune meter in the later ones. The exact time in which the meter registered an even number of cubic feet was noted with a stop match. To get an even number of cubic feet a definite number of revolutions of one of the dial hands was timed. This method is free from possible inaccuracies in the graduations of the meter registers.

The average readings from each test and the main steps of the computations have been placed on data sheets similar to those used in the friction-loss tests.

On several hydrants tests were run first with the pressure taken at the usual connection at the back of the barrel, and second with the pressures taken at a connection tapped into a cap screwed to the other outlet if a two-way hydrant, and to any one of the other outlets if the hydrant had more than two outlets. The plotted points from the two tests gave practically the same curve, showing that where more convenient there is no objection to using a tapped hydrant cap.

Curves. In addition to the rough plottings which, as already stated, were made as the work progressed, final curves were drawn from the completed results. It was from these curves, which give the best means of averaging the several experiments on any one hydrant, that the data for the tables designed for practical use were taken.

Figs. 22 to 43 inclusive show friction losses, giving actual friction losses for one coördinate and gallons per minute flowing for the other.

I

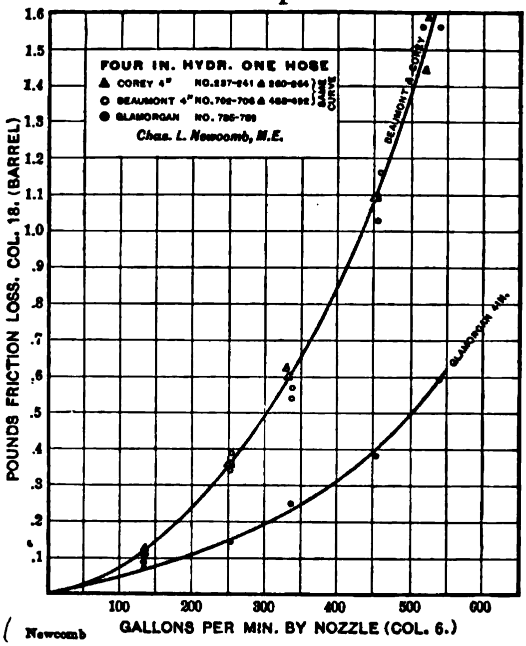


FIG. 22.

II

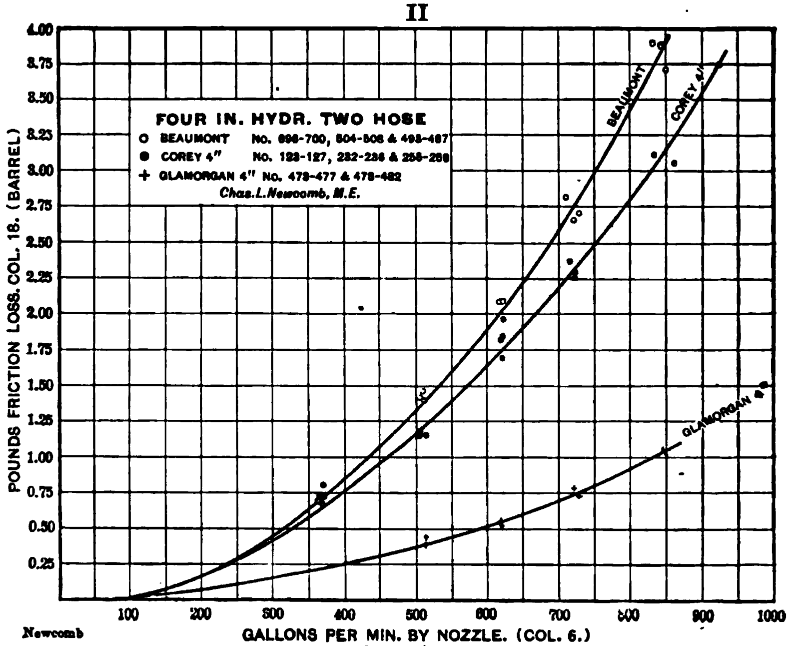


FIG. 23.

III

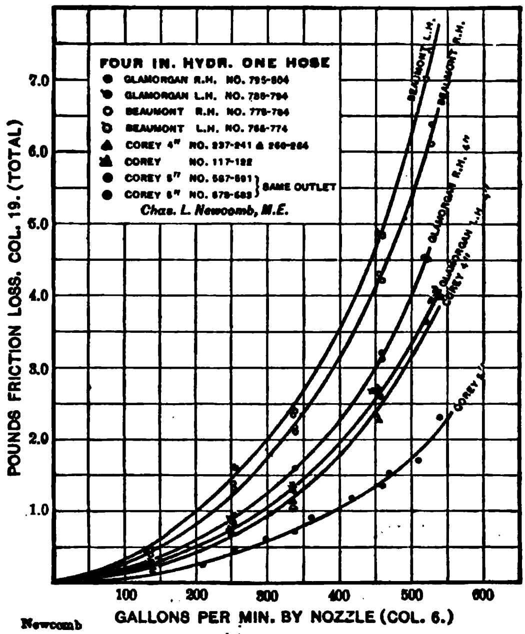


Fig. 24.

IV

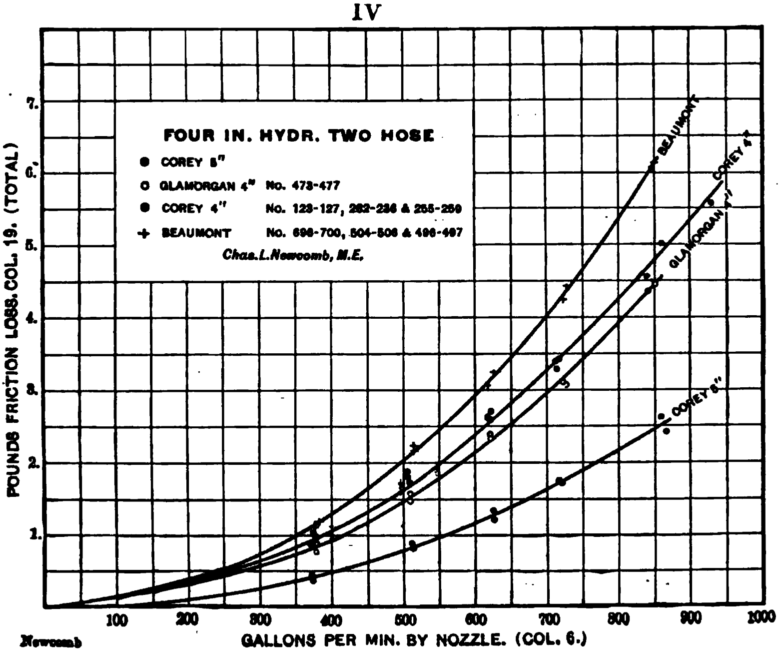


Fig 25.

V

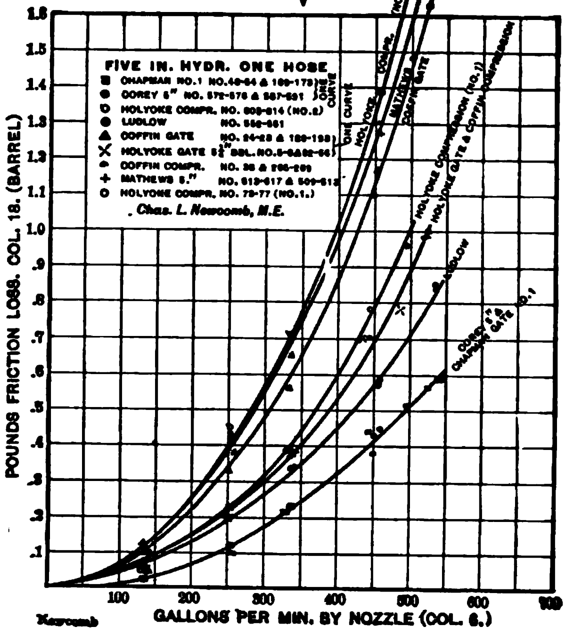


Fig. 26.

VI

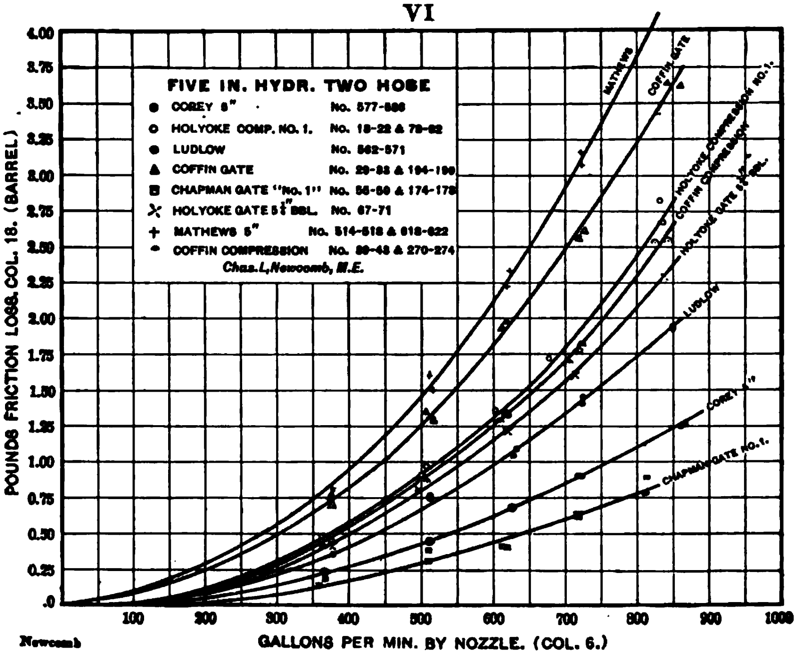


Fig. 27.

VII

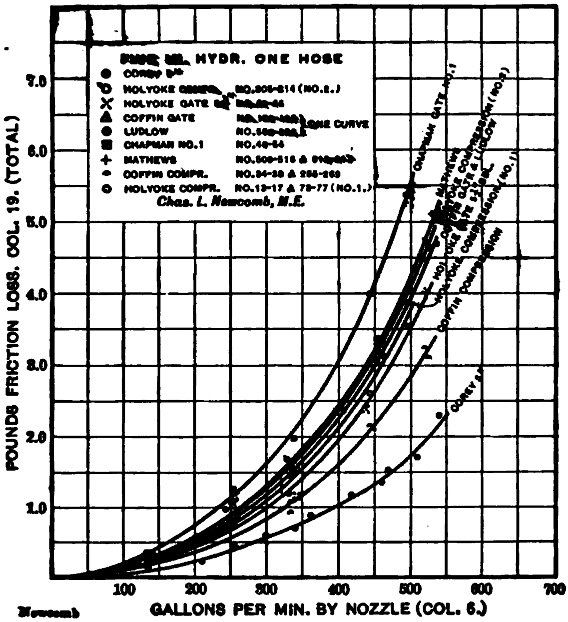


FIG. 28.

VIII

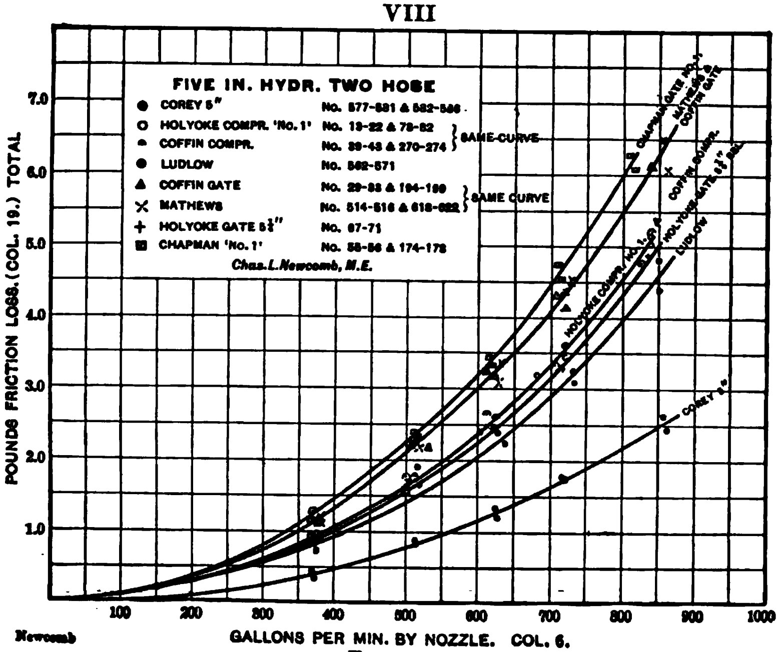


FIG. 29.

IX

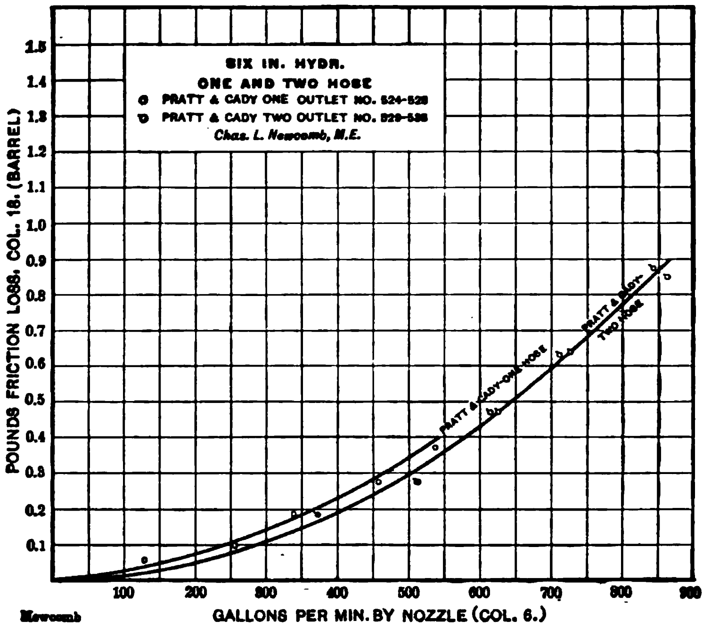


Fig. 30.

X

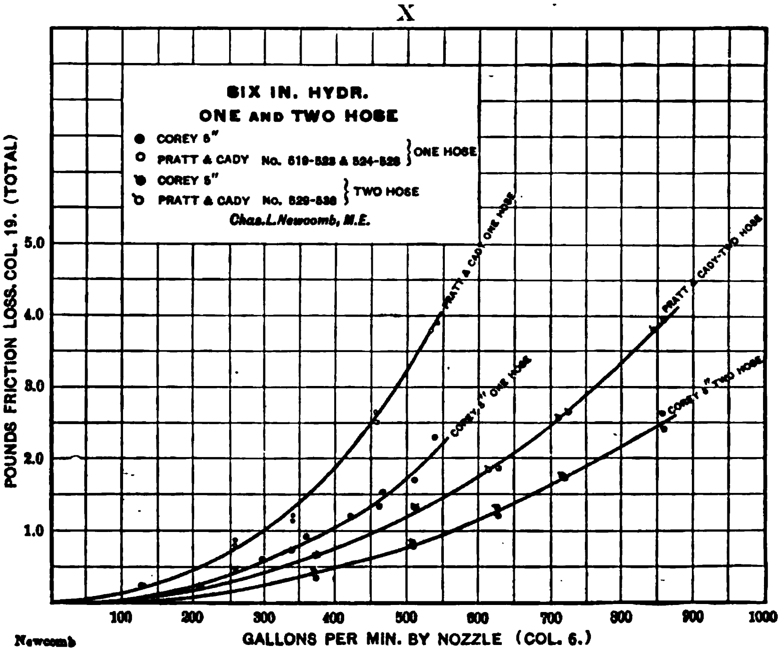


Fig. 31.

XI.

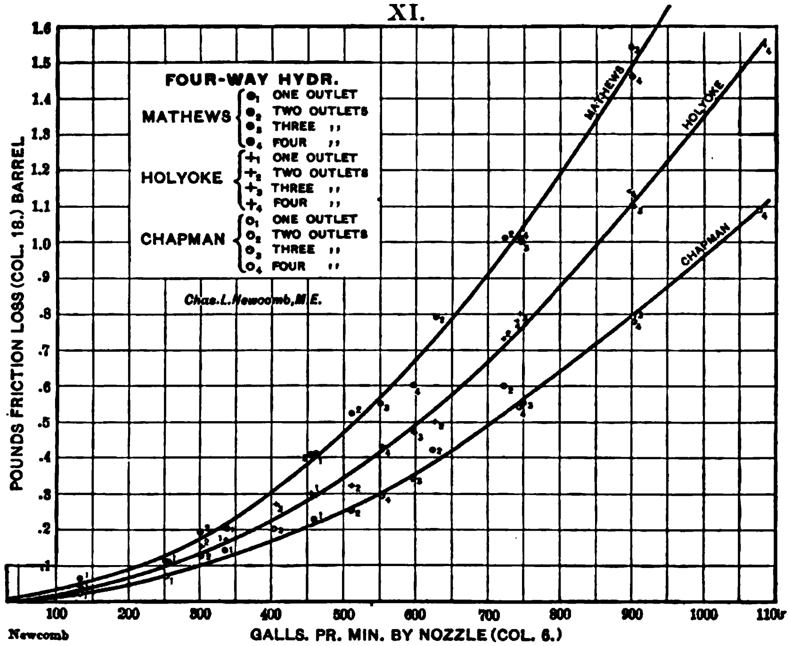


Fig. 32.

XII.

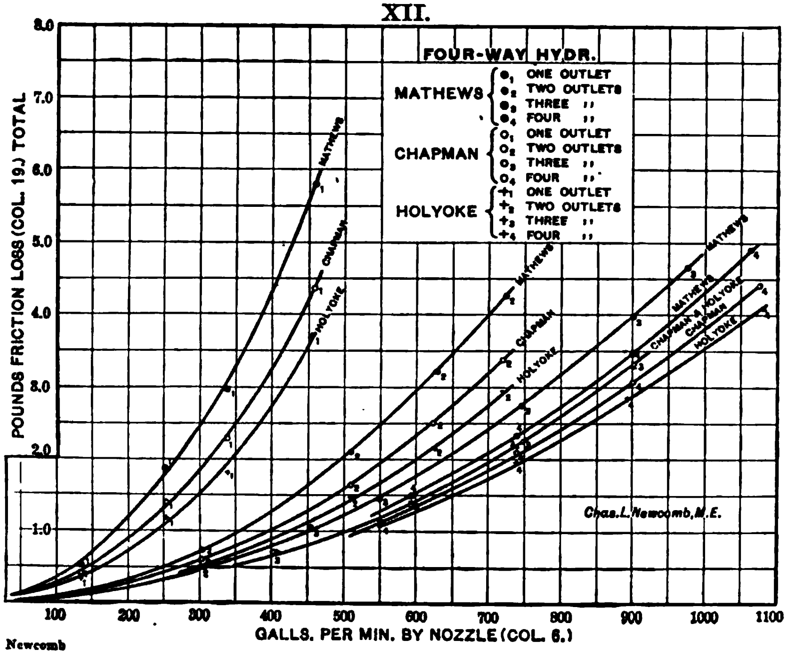


Fig. 33.

XIII

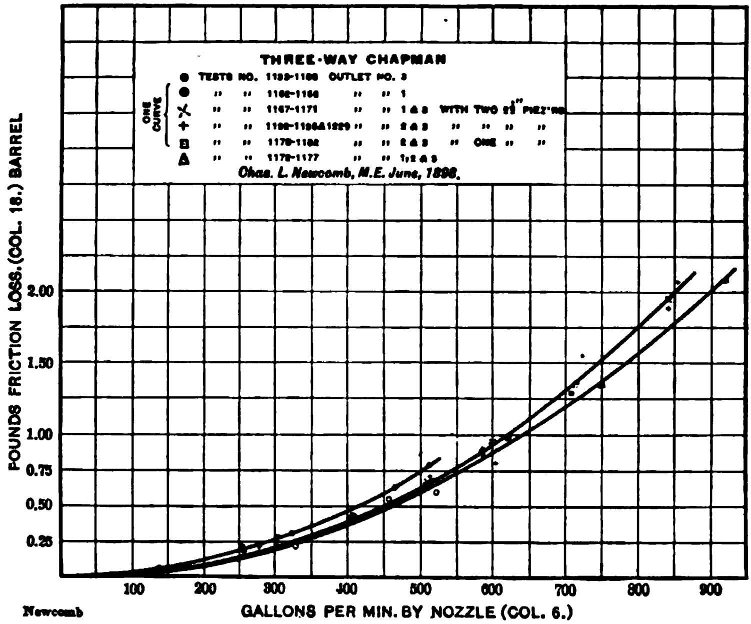


FIG. 34.

XIV

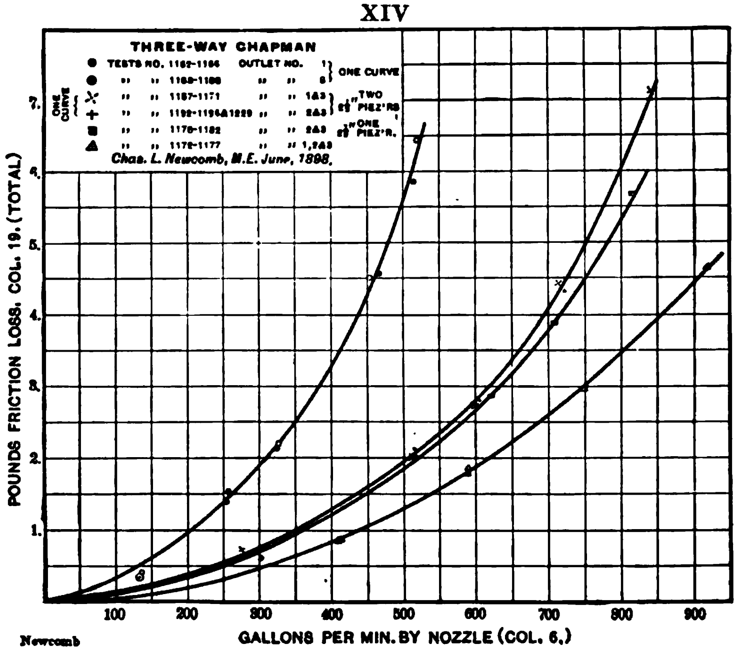


FIG. 35.

XV

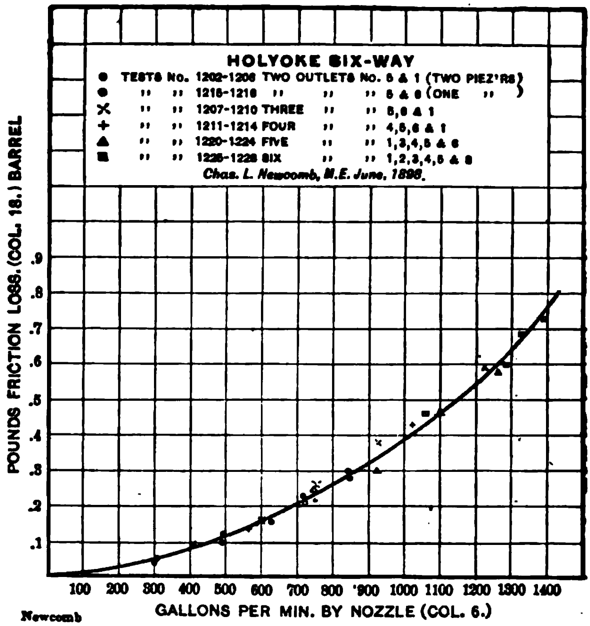


FIG. 36.

XVI

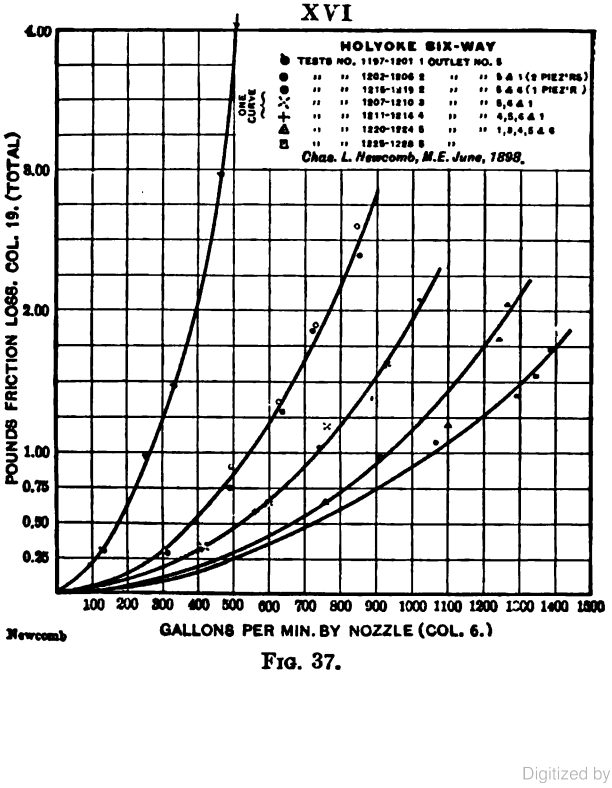


FIG. 37.

XVII

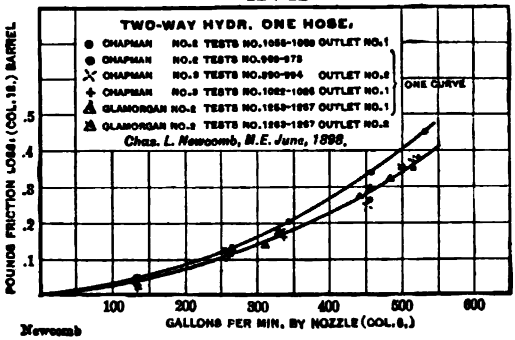


FIG. 38.

XVIII

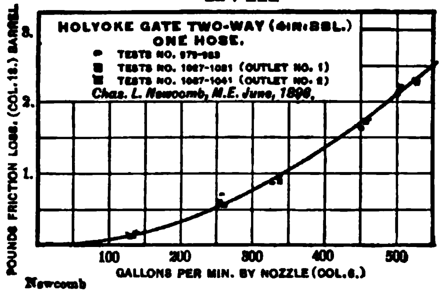


FIG. 39.

XIX

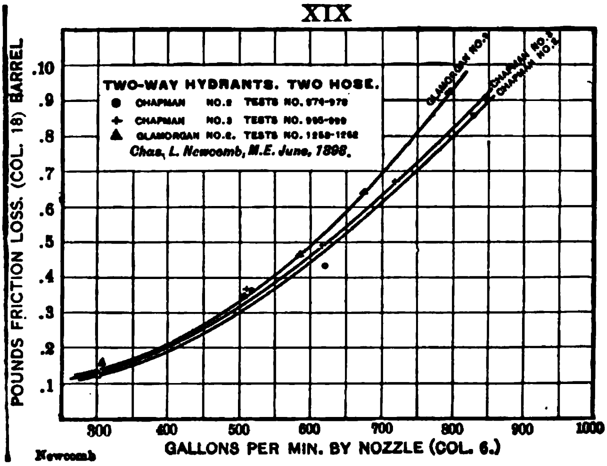


FIG. 40.

XX

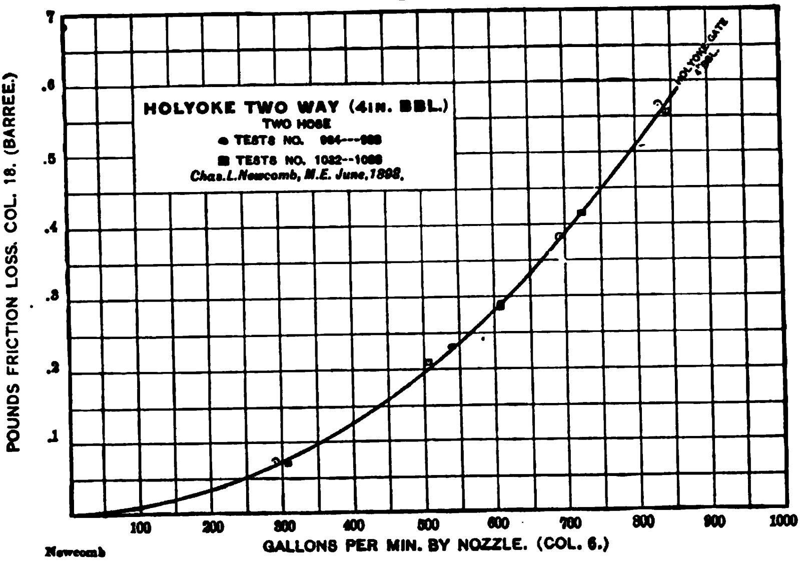


Fig. 41.

XXI

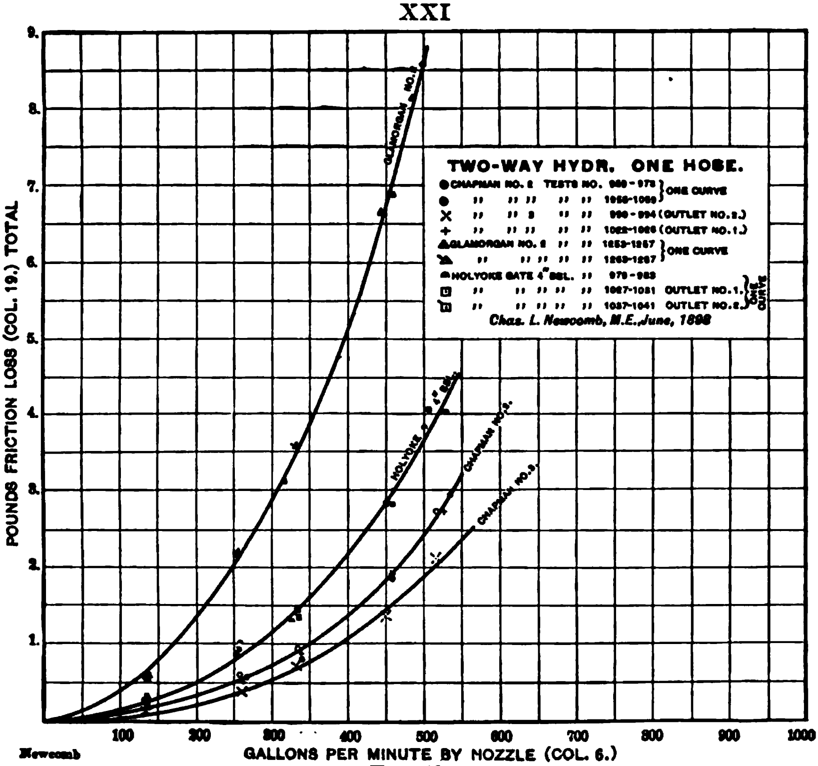


Fig. 42.

XXII

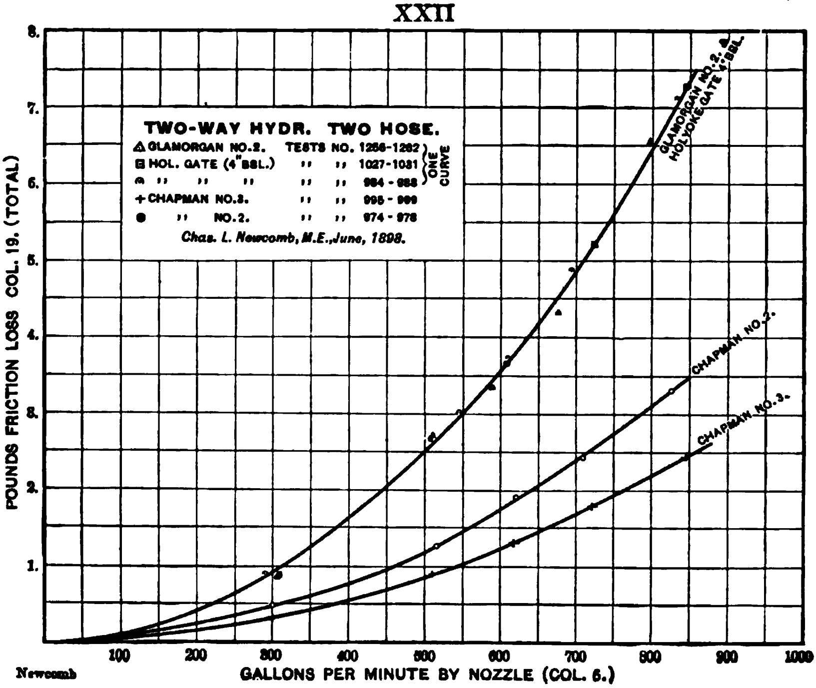

TWO-WAY HYDR. TWO HOSE.
△ GLAMORGAN NO.2. TESTS NO. 1256-1262
⊟ HOL. GATE (4" BBL.) " " 1027-1031
" " " " " 984-988
ONE CURVE
+ CHAPMAN NO.3. " " 995-999
● " NO.2. " " 974-978
Chas. L. Newcomb, M.E., June, 1898.
POUNDS FRICTION LOSS COL. 19. (TOTAL)
GALLONS PER MINUTE BY NOZZLE (COL. 6.)
GLAMORGAN NO.2. & HOLYOKE GATE 4" BBL.
CHAPMAN NO.2.
CHAPMAN NO.3.
Newcomb

FIG. 43.

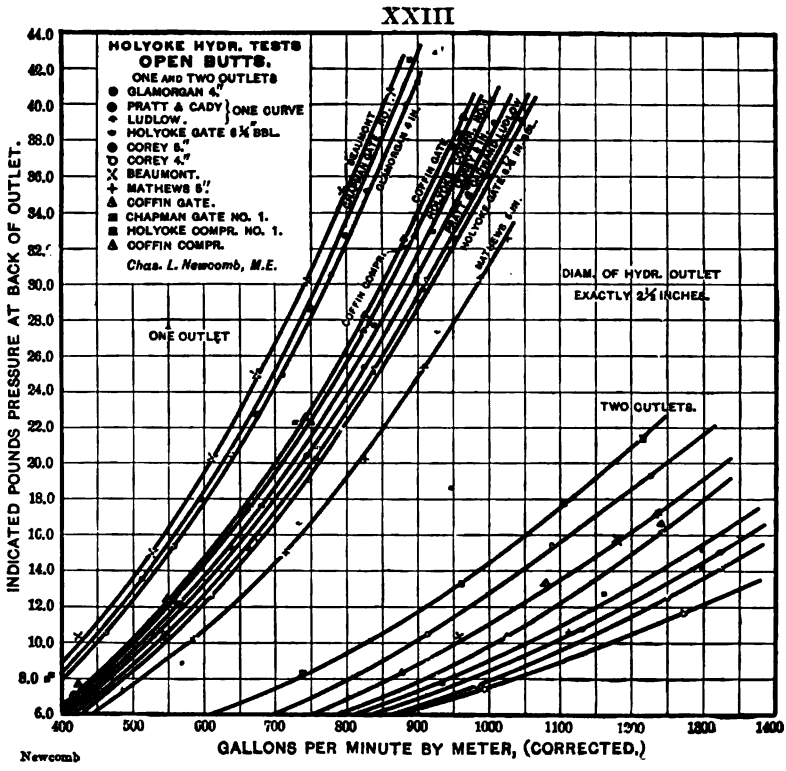

XXIII
HOLYOKE HYDR. TESTS
OPEN BUTTS.
ONE AND TWO OUTLETS
GLAMORGAN 4."
PRATT & CADY
LUDLOW.
ONE CURVE
HOLYOKE GATE 6¼" BBL.
COREY 5."
COREY 4."
BEAUMONT.
MATHEWS 5."
COFFIN GATE.
CHAPMAN GATE NO. 1.
HOLYOKE COMPR. NO. 1.
COFFIN COMPR.
Chas. L. Newcomb, M.E.
ONE OUTLET
DIAM. OF HYDR. OUTLET
EXACTLY 2½ INCHES.
TWO OUTLETS.
INDICATED POUNDS PRESSURE AT BACK OF OUTLET.
GALLONS PER MINUTE BY METER, (CORRECTED.)
Newcomb

FIG. 44.

XXIV

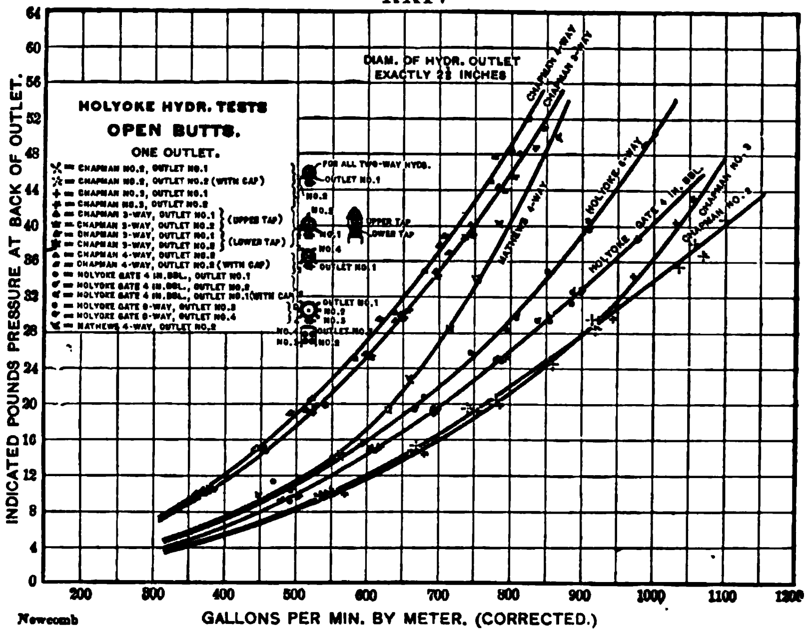


FIG. 45.

XXV

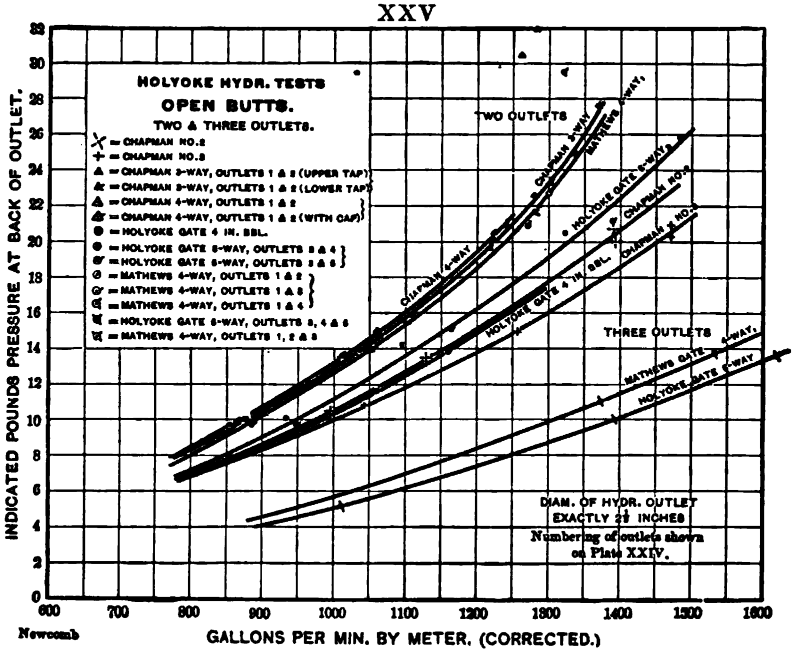


FIG. 46.

Figs. 44 to 46 give similar plottings for the open-butt tests, pressures at the back of the hydrant being taken for one coördinate, and gallons per minute for the other.

These curves give convenient means of studying the general uniformity of results and for interpolating between the points given in the summary tables. They also furnish a complete graphical record of the results which are shown in tabulated form on the data sheets. As many curves as were consistent with clearness have been plotted on one sheet, and in general hydrants of similar main dimensions will be found plotted together.

Accuracy. In the friction-loss tests the nozzle pressures were read to the nearest 0.1 pound, which represented a little less than one-quarter inch on the scale, and was, therefore, a very easily read division. The fluctuations under ordinary conditions, due to changes of pressure in the city mains, were less than one pound. When more than this, the unusual readings and the corresponding ones on the other gages were thrown out. It may safely be assumed that the nozzle pressures were correct within one-quarter of a pound. At the pressures worked at, this would mean an error in quantity of less than 1 per cent.

The U-gages in the later tests were read to the nearest 0.01 pound; in the earlier ones to the nearest 0.05 pound, except for the very small losses, where somewhat closer readings were made. At the small losses there was almost no vibration of the mercury columns, thus facilitating accurate readings. For the larger losses careful throttling of the cocks reduced the vibrations to a small range. By plotting these losses with the quantities corresponding, and locating an average curve through the points, the errors tend to neutralize each other, and it will be seen by studying the plates that the points do very readily locate such curves and that but few of them lie far outside the average line. Losses read from these curves may be considered correct within 2 per cent. Table I and the pyramid diagrams were made from the curves.

In the open-butt tests the mercury column was read to the nearest 0.1 pound. The average pressure from the ten readings would probably not be in error more than 0.2 pound and

in general not more than 0.1 pound. In the tests where the mercury column was connected to the 6-inch piezometer the U-gage error also enters, but in general this did not exceed about 0.1 pound. This means, when using the U-tube, a maximum error of 0.3 pound, and without the tube, 0.2 pound. The percentage errors decrease with the increase of pressures.

In estimating on the meter just when the dial hand with the meter in motion passes the zero point, an error of 1½ cubic feet might be made. If the errors at the beginning and end happen to be the opposite direction, the maximum error would be 3 cubic feet. One hundred cubic feet was the smallest quantity passed in any test, and generally the quantity was considerably larger. Therefore in the worst case the percentage error in reading the meter does not exceed 3 per cent. The meters were calibrated by the nozzles, and an average curve plotted with meter readings for one coördinate, and nozzle quantities for the other. The errors in the meters were found to be practically constant for any given quantity, so that an error of over 1 per cent. in the calibration is improbable.

The stop-watch was read to the nearest one-fifth second and was frequently rated so that with ordinary care the time should be correct within 1 per cent., and often closer. With the above errors happening to be all in one direction the determination of the discharge per minute in any one test might be 5 per cent. out. This would be the worst condition, and in general the error would be much less.

In this work, as in the friction-loss tests, the results were plotted and average curves drawn. The results from these curves may reasonably be expected to be correct within 3 per cent.

Considering all the above, it will be seen that the results are amply accurate for all practical purposes.

HYDRANTS TESTED.

The following cuts, arranged in alphabetical order, show the general features and dimensions of the hydrants tested. A study of the results of the tests in connection with these cuts will show the reasons for the differences found.

Beaumont. Fig. 4 shows the general appearance of the hydrant tested. The casting towards the outlets was well rounded and the nozzles leaded in, making a smooth joint.

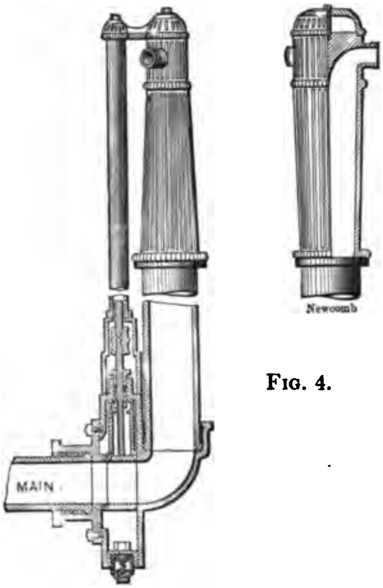


FIG. 4.

Inside diameter of cylindrical barrel, 4⅛ inches.

Diameter of gate opening, 4⅛ inches.

Fig. 5 shows a cross-section of hydrant barrel at gage connection.

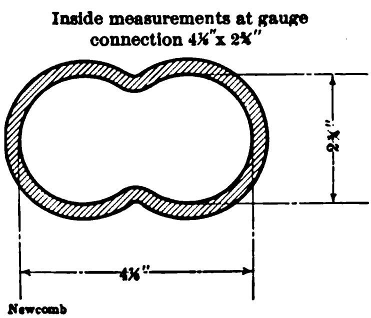


FIG. 5.

Chapman Nos. 1 and 2. Fig. 6 shows the general appearance of hydrants Nos. 1 and 2, but the hydrants tested were simple two-ways with no steamer connections. The dimensions given are for the hydrants tested. No. 1 was the regular commercial hydrant, and had sharp, jagged corners at the 2½-inch outlets. In No. 2 the same casting was used, but the corners had been chipped and filed and made as smooth as possible, working from the outside. The result was fairly smooth curves, but of short radius, probably about ¼ inch.

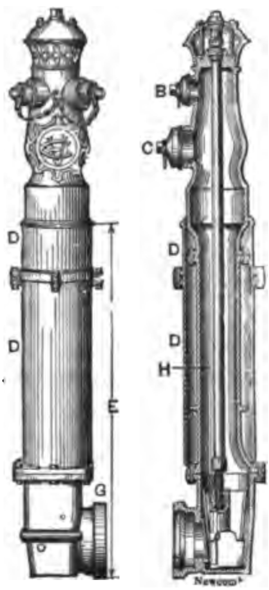


FIG. 6.

Gage connection: inside diameter of barrel at point opposite B

For No. 1, 4⅝ inches.
For No. 2, 5 inches.

Smallest inside diameter of barrel, 5¼ inches.

Diameter of gate opening, 5 inches.

Chapman No. 3. Fig. 7 shows the new-pattern hydrant called No. 3. This was a two-way with steamer connection. The casting at $2\frac{1}{2}$-inch outlets was smooth and well-rounded. Nozzles did not butt close against casting, but left a groove-like space about $\frac{1}{16}$ inch across.

FIG. 7.

Inside diameter of barrel at gage connections, $7\frac{3}{4}$ inches.

Inside diameter of cylindrical barrel, 7 inches.

Gate opening, oval, $6\frac{3}{8}$ inches by $5\frac{7}{16}$ inches; equal in area to circle 5. Nine inches diameter.

Chapman Three-Way. Fig. 8 shows the three-way independent gate hydrant. Nozzles projected into hydrant about $\frac{1}{4}$ inch and had flat ends, making sharp corners. The independent gate arrangement differs somewhat from that in the four-way hydrant. The guides are cast with the head and have rounded corners toward the current. The inside independent valve, when wide open, projects $\frac{1}{8}$ inch to $\frac{3}{16}$ inch into nozzle openings.

Barrel at gage connection, hexagonal; distance inside between flat faces, $6\frac{9}{16}$ inches.

Round inside diameter, 6 inches.

Cylindrical barrel inside diameter, $6\frac{5}{8}$ inches.

Gate opening, oval, $5\frac{7}{16}$ inches by $4\frac{5}{16}$ inches.

FIG. 8.

Chapman Four-Way. Fig. 9 shows the four-way independent gate hydrant. The lowest point on the independent gates projected about $\frac{1}{4}$ inch into openings when gates were wide open. This caused a noticeable breaking of the stream in the open butt tests.

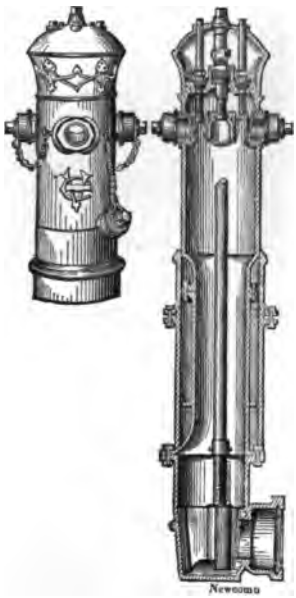


FIG. 9.

Gage connection: inside diameter of barrel, $8\frac{1}{4}$ inches.

Inside diameter of cylindrical barrel, $6\frac{3}{8}$ inches.

Diameter of gate opening, $6\frac{1}{16}$ inches.

Coffin Gate. Fig. 10 shows general appearance of Coffin hydrant, but the one tested had no steamer connection. Dimensions below are for hydrant tested. The nozzle entrances had well-rounded corners.

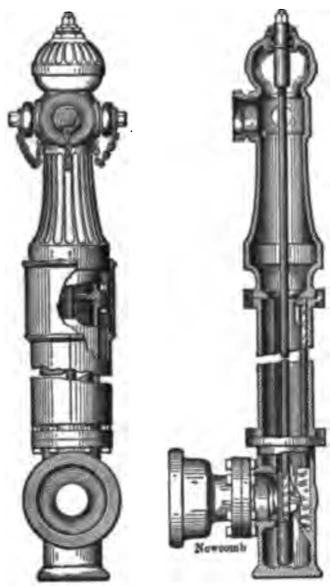


Fig. 10.

Inside diameter at gage connection, 6 inches.

Diameter at contraction, $5\frac{3}{8}$ inches.

Inside diameter of cylindrical barrel, $6\frac{1}{2}$ inches.

Diameter of gate opening, $4\frac{3}{4}$ inches.

Coffin Compression. Fig. 11 shows a two-way hydrant with steamer connection. The 2½-inch nozzle entrances had well-rounded corners. This pattern has no contracted section like that in the gate hydrant.

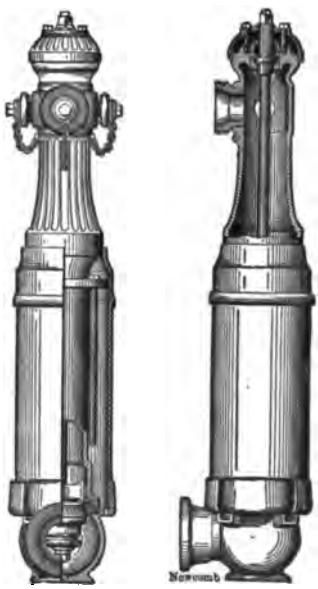


FIG. 11.

Inside diameter of gage connection, 6 inches.

Inside diameter of cylindrical barrel, 6 inches.

Diameter of gate opening, 5 inches.

Corey 4- and 5-Inch. Fig. 12 shows the general features of both 4-inch and 5-inch barrel hydrants. They were both two-ways and identical except for size. In this hydrant the barrel gage connection was enough below the outlet to enter the cylindrical part of the barrel.

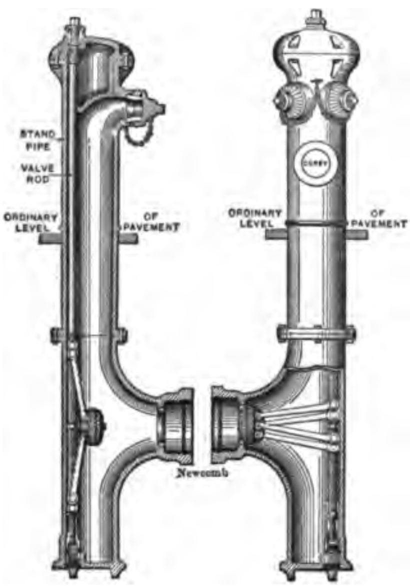


FIG. 12.

Inside diameters at gage connection:

For 4-inch barrel, $5\frac{3}{4}$ inches.
For 5-inch barrel, $6\frac{3}{4}$ inches.

Inside diameters of cylindrical barrel:

For 4-inch barrel, 4 inches.
For 5-inch barrel, 5 inches.

Diameters of gate opening:

For 4-inch barrel, 4 inches.
For 5-inch barrel, 5 inches.

Glamorgan. Fig. 13 shows the general features of the Glamorgan hydrants referred to as Nos. 1 and 2. The castings of both hydrants were similar except that the outlets of No. 1 were less than 180 degrees apart, or about like the ordinary hydrant. The nozzle outlets were not rounded, but presented square corners in the barrel.

No. 2 was fitted with independent cut-offs attached to outlets. These were of a peculiar design, working on the principle of a piston valve, the shutting off being accomplished by revolving an external collar which moved the valves over the ports. The ports compelled the water to make several turns over sharp corners, accounting for a large frictional loss.

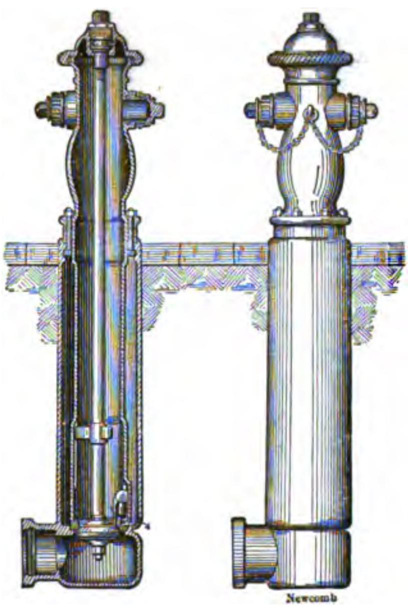


FIG. 13.

Inside diameters at gage connection:

For No. 1, $4\frac{3}{8}$ inches.
For No. 2, $6\frac{1}{2}$ inches.

Inside diameters of barrel at smallest part:

For No. 1, 5 inches.
For No. 2, $6\frac{3}{4}$ inches.

Diameters of gate opening:

For No. 1, $4\frac{1}{4}$ inches.
For No. 2, $6\frac{5}{8}$ inches.

Holyoke Gate (4-inch, 5¼-inch, and 6¼-inch barrel). Fig. 14 shows the general features of the nominal 4-inch, 5-inch, and 6-inch hydrants. These were all two-way. Casting at outlet had rounding corners, but was rough, with small nubbles and projections.

FIG. 14.

Inside diameters at gage connections:
For 4-inch hydrant, $5\frac{9}{16}$ inches.
For 5-inch hydrant, $6\frac{1}{8}$ inches.
For 6-inch hydrant, 7 inches.

Inside diameters of cylindrical barrel:
For 4-inch hydrant, $4\frac{3}{8}$ inches.
For 5-inch hydrant, $5\frac{3}{8}$ inches.
For 6-inch hydrant, $6\frac{3}{8}$ inches.

Diameters of gate opening:
For 4-inch hydrant, $4\frac{1}{16}$ inches.
For 5-inch hydrant, 5 inches.
For 6-inch hydrant, 6 inches.

Holyoke Compression Nos. 1 and 2. Fig. 15 shows the general features of hydrants Nos. 1 and 2, which were both two-way. The casting at outlet had rounding corners, but was rough, with small nubbles and projections.

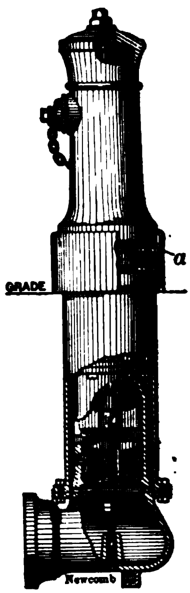


FIG. 15.

Inside diameters at gage connections:
For No. 1, 6¼ inches.
For No. 2, 5⅝ inches.

Inside diameters of cylindrical barrel:
For No. 1, 5¼ inches.
For No. 2, 5 inches.

Diameters of gate opening;
For No. 1, 5½ inches.
For No. 2, 4½ inches.

Holyoke Four-Way. Fig. 16 shows an independent gate hydrant, the condition at the nozzles being as shown in the cut.

FIG. 16.

Inside diameter of barrel at gage connection, 7½ inches.

Inside diameter of cylindrical barrel, 6⅜ inches.

Diameter of gate opening, 6 inches.

Holyoke Six-Way. Fig. 17 shows the general appearance of the six-way independent gate hydrant tested. The main gate and barrel are of the same style as shown in Fig 14. The independent gates at the nozzle outlets are similar to those shown in Fig. 16.

FIG. 17.

Inside diameters at gage connections:
For upper connection, $9\frac{1}{8}$ inches.
For lower connection, $9\frac{7}{8}$ inches.

Inside diameter of cylindrical barrel, 10 inches.

Diameter of gate opening, 8 inches.

Ludlow. Fig. 18 shows a simple two-way hydrant. The nozzle outlets were square-cornered, the sketch well showing the conditions.

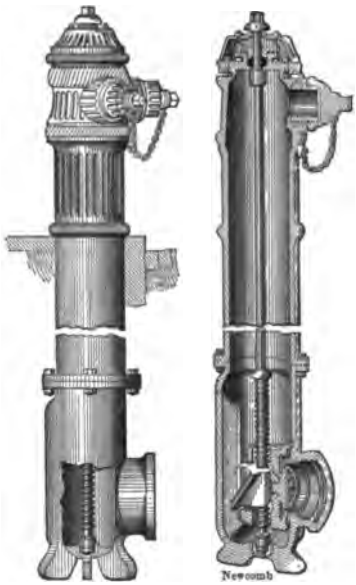


FIG. 18.

Inside diameter at gage connection, 7⅝ inches.

Inside diameter of cylindrical barrel, 7 inches.

Diameter of gate opening, 5 inches.

Mathews 5-Inch. Fig. 19 shows the general appearance of the two-way compression hydrant, with steamer connection, tested. The hydrant was fitted with the double-valve arrangement, as shown in Fig. 19A. The casting of hydrant was rounded at the outlets to a radius of about ½ inch, not having the square corners shown in the cut.

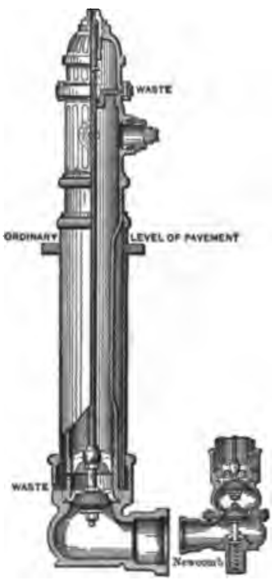


FIG. 19. FIG. 19A.

Inside diameter at gage connection, $7\frac{7}{16}$ inches.

Inside diameter of cylindrical barrel, 4 inches.

Diameter of both gate openings, $5\frac{5}{16}$ inches.

Mathews Four-Way. Fig. 20 shows the general appearance of a single-valve compression hydrant with independent gates at outlet. Fig. 19 shows the main valve arrangement of the hydrant tested, and Fig. 20 shows the design of the independent gates. In the hydrant tested the head was of somewhat different design to provide for the two additional outlets directly above those shown. When open the distance from valve face to outlet is from $1\frac{1}{2}$ inches to $1\frac{5}{8}$ inches.

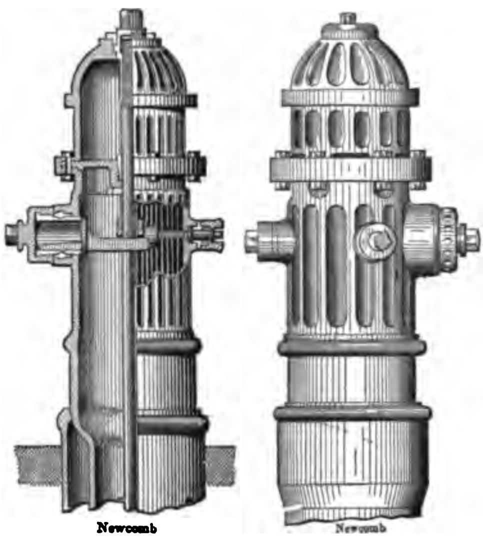


Fig. 20.

Inside diameter at gage connection, $8\frac{1}{2}$ inches.

Inside diameter of cylindrical barrel, $6\frac{1}{4}$ inches.

Diameter of gate opening, $6\frac{3}{8}$ inches.

Pratt & Cady. Fig. 21 shows the general appearance of the two-way hydrant tested, with steamer connection. The hydrant tested was fitted with independent gates for the 2½-inch outlets. These gates were moved up and down by spindles through the head, somewhat similar to the Chapman and Holyoke hydrants, but the gates themselves had rounding surfaces following the curvatures of the barrel. The casting at the outlets had square and rather ragged corners.

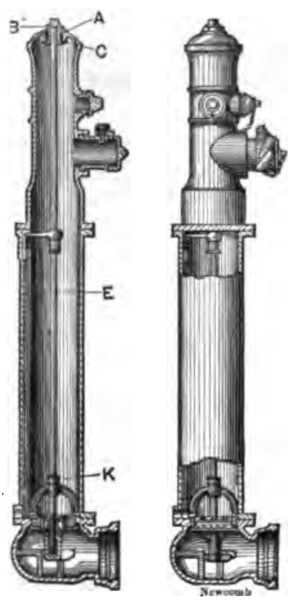


FIG. 21.

Inside diameter at gage connections, 6 inches.

Diameter of cylindrical barrel, 8⅜ inches.

Diameter of gate inlet, 6¼ inches.

THE RESULTS IN BRIEF.

To put the results into shape for ready use the tables following have been prepared: Tables I, II, and III give the entire results of the friction-loss tests; Tables IV and V, the discharging capacity of open butts for the range of pressures covered by the tests. These tables were filled out by readings directly from the curves, Figs. 22 to 43 inclusive.

To further aid in making comparisons and to put all the friction-loss data into shape to appeal quickly to the eye, the pyramid diagrams, Figs. 47, 48, and 49, have been prepared. The points selected for these diagrams correspond to one or more standard fire streams; that is, 250 gallons per minute through each line of 2½-inch fire hose.

The open-butt tables are of value in testing water-works systems to determine their capacities at useful pressures where either lack of time or facilities prevents using more accurate apparatus. In such cases the open butt gives, quickly and inexpensively, fairly accurate results for this kind of work. Differences in design and construction of the outlet materially affect the discharge, but a study of the tables, together with the cuts of the hydrants, will enable one to apply intelligent corrections for outlets differing from any here tested.

In practice the gage would often be connected into a tapped hole in a hydrant cap and the cap screwed to one of the other outlets of the hydrant if it had more than one. This in all ordinary cases would give the same result as a connection tapped into the back of the hydrant, as was the case in most of the tests. The few tests in which the gage was connected first one way and then the other show practically no difference in the result.

TABLE I.

Hydrant Friction Losses—One Stream Flowing.

Friction Loss in Pounds with Various Rates of Flow.

Gallons per Minute Flowing.

Name of Hydrant.	100			200			300			400			500		
	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
B'um't { L. H. outlet	0.07	0.25	0.32	0.23	0.76	0.99	0.49	1.49	1.98	0.85	2.68	3.53	1.36	4.89	6.25
B'um't { R. H. "	0.07	0.18	0.25	0.23	0.59	0.82	0.49	1.24	1.73	0.85	2.24	3.09	1.36	3.99	5.35
Chapman No. 1	0.01	0.19	0.20	0.07	0.69	0.76	0.17	1.47	1.64	0.32	2.74	3.06	0.51	4.98	5.49
" No. 2	0.03	0.05	0.08	0.08	0.26	0.34	0.16	0.58	0.74	0.27	1.11	1.38	0.40	2.05	2.45
" No. 3	0.02	0.01	0.03	0.07	0.15	0.22	0.14	0.41	0.55	0.22	0.87	1.09	0.34	1.55	1.89
Chapman 3-way	0.03	0.32	0.35	0.12	0.84	0.96	0.27	1.61	1.88	0.47	2.80	3.27	0.73	4.87	5.60
" 4-way	0.01	0.24	0.25	0.04	0.82	0.86	0.10	1.72	1.82	0.17	3.03	3.20	0.25	....	.....
Coffin Gate..........	0.06	0.08	0.14	0.22	0.31	0.53	0.48	0.72	1.20	0.86	1.37	2.23	1.44	2.48	3.92
" Compression.	0.05	0.05	0.10	0.15	0.23	0.38	0.30	0.55	0.85	0.53	1.07	1.60	0.88	1.95	2.83
Corey 4-in..........	0.07	0.04	0.24	0.23	0.19	0.42	0.49	0.44	0.93	0.85	0.93	1.78	1.37	1.76	3.13
" 5-"	0.01	0.03	0.04	0.07	0.18	0.25	0.17	0.41	0.58	0.32	0.73	1.05	0.51	1.21	1.72
Glamorgan, No. 1..	0.05	0.10	0.15	0.11	0.39	0.50	0.19	0.87	1.06	0.31	1.63	1.94	0.49	2.83	3.32
" No. 2..	0.02	0.37	0.39	0.07	1.29	1.36	0.14	2.73	2.87	0.22	4.88	5.10	0.34	8.28	8.62
Holyoke Gate, 4-in.	0.10	0.03	0.13	0.35	0.14	0.49	0.77	0.38	1.15	1.36	0.81	2.17	2.10	1.57	3.67
Holyoke Gate, 5½-in.	0.05	0.07	0.12	0.15	0.29	0.44	0.30	0.70	1.00	0.53	1.41	1.94	0.88	2.61	3.49
" " 6½-"	0.03	0.07	0.10	0.12	0.28	0.40	0.26	0.60	0.86	0.49	1.10	1.59	0.82	1.79	2.61
" Comp. No. 1.	0.05	0.08	0.13	0.15	0.33	0.48	0.32	0.79	1.11	0.59	1.53	2.12	1.01	2.74	3.75
" " No. 2.	0.07	0.24	0.31	0.26	0.33	0.59	0.56	0.72	1.28	1.03	1.32	2.35	1.68	2.42	4.10
Hol'ke Gate, 4-way.	0.01	0.19	0.20	0.06	0.64	0.70	0.13	1.37	1.50	0.22	2.48	2.70	0.34	....	.....
" " 6-way.	....	....	0.21	....	....	0.62	....	....	1.23	....	....	2.08	....	....	3.85
Ludlow	0.04	0.10	0.14	0.13	0.40	0.53	0.26	0.94	1.20	0.45	1.78	2.23	0.71	3.21	3.92
Mathews 5 in.......	0.07	0.09	0.16	0.25	0.34	0.59	0.54	0.76	1.30	0.97	1.46	2.43	1.56	2.69	4.25
Mathews 4-way.....	0.03	0.29	0.32	0.09	1.09	1.18	0.18	2.22	2.40	0.31	3.99	4.30	0.47	....	.....
Pratt & Cady.......	0.02	0.12	0.14	0.07	0.39	0.46	0.14	0.87	1.01	0.23	1.68	1.91	0.34	2.92	3.26

TABLE II.

Hydrant Friction Losses—Two Streams Flowing.

Friction Loss in Pounds with Various Rates of Flow.

Gallons per Minute Flowing.

Name of Hydrant.	300			400			500			600			700			800		
	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
B'um't { L. H. outlet	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
B'um't { R. H. "	0.45	0.28	0.73	0.82	0.48	1.30	1.32	0.70	2.02	1.87	1.04	2.91	2.57	1.44	4.01	3.41	1.94	5.35
Chapman No. 1	0.08	0.74	0.82	0.17	1.32	1.49	0.30	1.97	2.28	0.44	2.79	3.23	0.61	3.86	4.47	0.78	5.24	6.02
" No. 2	0.12	0.36	0.48	0.19	0.58	0.77	0.30	0.88	1.18	0.44	0.30	1.74	0.61	1.79	2.40	0.80	2.30	3.10
" No. 3	0.13	0.19	0.32	0.20	0.33	0.53	0.31	0.51	0.82	0.46	0.75	1.21	0.63	1.04	1.67	0.82	1.36	2.18
Chapman 3-way	0.20	0.55	0.75	0.38	0.91	1.29	0.62	1.33	1.95	0.92	1.86	2.78	1.30	2.75	4.05	1.75	4.24	5.99
" 4-way	0.10	0.48	0.58	0.17	0.84	1.01	0.25	1.33	1.58	0.36	1.95	2.31	0.49	2.69	3.18	0.64	....	.....
Coffin Gate..........	0.50	0.25	0.75	0.82	0.54	1.36	1.26	0.86	2.12	1.82	1.20	3.02	2.48	1.61	4.09	3.23	2.25	5.48
" Compression.	0.28	0.35	0.63	0.55	0.53	1.08	0.87	0.78	1.65	1.26	1.14	2.40	1.71	1.63	3.34	2.30	2.29	4.59
Corey 4-in..........	0.42	0.23	0.65	0.75	0.32	1.07	1.16	0.47	1.63	1.62	0.73	2.35	2.18	1.06	3.24	2.78	1.49	4.27
" 5-"	0.14	0.12	0.26	0.27	0.22	0.49	0.43	0.35	0.78	0.62	0.54	1.16	0.86	0.78	1.64	1.11	1.08	2.19
Glamorgan, No. 1..	0.17	0.42	0.59	0.26	0.67	0.93	0.37	1.07	1.44	0.51	1.60	2.11	0.69	2.26	2.95	0.92	3.01	3.93
" No. 2..	0.14	0.78	0.92	0.21	1.41	1.62	0.33	2.17	2.50	0.48	3.07	3.55	0.69	4.15	4.84	0.93	5.54	6.47
Holyoke Gate, 4-in.	0.72	0.20	0.92	1.24	0.38	1.62	1.94	0.56	2.50	2.81	0.74	3.55	3.87	0.97	4.84	5.10	1.37	6.47
Holyoke Gate, 5½-in.	0.25	0.35	0.60	0.48	0.54	1.02	0.79	0.78	1.57	1.15	1.12	2.27	1.57	1.60	3.17	2.08	2.29	4.37
" " 6½-"	0.25	0.17	0.42	0.47	0.30	0.77	0.74	0.48	1.22	1.09	0.68	1.77	1.48	1.00	2.48	....	....	3.36
" Comp. No. 1.	0.31	0.32	0.63	0.58	0.50	1.08	0.92	0.73	1.65	1.30	1.10	2.40	1.80	1.54	3.34	2.44	2.15	4.59
" " No. 2.	....	....	.....	....	....	.....	....	....	.....	....	....	.....	....	....	.....	....	....	.....
Hol'ke Gate, 4-way.	0.13	0.35	0.48	0.22	0.65	0.87	0.34	1.03	1.37	0.49	1.51	2.00	0.67	2.08	2.75	0.88	...	.....
" " 6-way.	0.05	0.26	0.31	0.08	0.47	0.55	0.12	0.73	0.85	0.16	1.05	1.21	0.21	1.45	1.66	0.26	1.97	2.23
Ludlow	0.22	0.34	0.56	0.41	0.51	0.92	0.67	0.75	1.42	0.98	1.08	2.06	1.34	1.57	2.91	1.74	2.26	4.00
Mathews 5 in.......	0.57	0.18	0.75	0.95	0.41	1.36	1.47	0.65	2.12	2.12	0.90	3.02	2.92	1.17	4.09	3.83	1.65	5.48
Mathews 4-way.....	0.18	0.51	0.69	0.31	0.96	1.27	0.47	1.55	2.02	0.68	2.27	2.95	0.91	3.09	4.00	1.19	....	.....
Pratt & Cady.......	0.11	0.31	0.42	0.19	0.58	0.77	0.29	0.93	1.22	0.43	1.34	1.77	0.59	1.89	2.48	0.77	2.59	3.36

TABLE III.

Hydrant Friction Losses—Three to Six Streams Flowing.

Name of Hydrant and Gallons per Minute Flowing.	No. of Streams Flowing.	Friction Loss in Pounds with Various Rates of Flow.														
		Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.
Gallons per Min.		500			600			700			800			900		
Chapman 3-way .	3	0.60	0.70	**1.30**	0.87	1.01	**1.88**	1.18	1.42	**2.60**	1.56	1.89	**3.45**	2.00	2.40	**4.40**
" 4-way .	3	0.25	0.70	**0.95**	0.36	1.05	**1.41**	0.49	1.46	**1.95**	0.64	1.96	**2.60**	0.80	2.51	**3.31**
Holyoke 4-way ..	3	0.35	0.60	**0.95**	0.49	0.92	**1.41**	0.67	1.28	**1.95**	0.88	1.72	**2.60**	1.11	2.20	**3.31**
" 6-way ..	3	0.12	0.35	**0.47**	0.16	0.50	**0.66**	0.21	0.69	**0.90**	0.26	0.92	**1.18**	0.32	1.21	**1.53**
Mathews 4-way ..	3	0.47	0.73	**1.20**	0.68	1.07	**1.75**	0.91	1.49	**2.40**	1.19	1.97	**3.16**	1.49	2.51	**4.00**
Gallons per Min.		600			700			800			900			1,000		
Chapman 4-way .	4	0.36	0.97	**1.33**	0.49	1.34	**1.83**	0.64	1.76	**2.40**	0.80	2.25	**3.05**	0.96	2.84	**3.80**
Holyoke 4-way ..	4	0.49	0.76	**1.25**	0.67	1.04	**1.71**	0.88	1.38	**2.26**	1.11	1.75	**2.86**	1.35	2.20	**3.55**
" 6-way ..	4	0.16	0.50	**0.66**	0.21	0.69	**0.90**	0.26	0.92	**1.18**	0.32	1.21	**1.53**	0.38	1.57	**1.95**
Mathews 4-way ..	4	0.68	0.84	**1.52**	0.91	1.16	**2.07**	1.19	1.53	**2.72**	1.49	2.04	**3.45**	1.81	....	**4.32**
Gallons per Min.		1,100			1,200			1,300			1,400			1,500		
Holyoke 6-way. .	5	0.46	0.98	**1.44**	0.54	1.21	**1.75**	0.63	1.47	**2.10**	0.75	....	....	0.91	....	....
" 6-way...	6	0.46	0.61	**1.07**	0.54	0.71	**1.25**	0.63	0.85	**1.48**	0.75	1.00	**1.75**	0.91	1.14	**2.05**

TABLE IV.

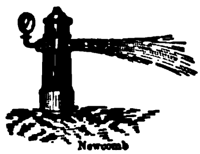


FIG. 209.

DISCHARGE OF ONE OPEN HYDRANT BUTT.

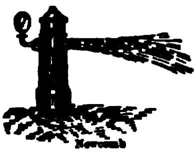
These figures apply only approximately to hydrants in general, because slight variations in construction, even in hydrants from the same shop, considerably affect the discharge from the open butt. The cuts of hydrants will suggest corrections, so that with good judgment results accurate within from 10 to 20 per cent. may, in general, be obtained.

NAME OF HYDRANT.	DISCHARGE THROUGH ONE OPEN BUTT OF HYDRANT WITHOUT HOSE ATTACHED. (DIAMETER OF OUTLET EXACTLY 2½ INCHES.) GALLONS PER MINUTE. Hydrant Pressure indicated while Stream is Flowing, by Gauge attached to Hydrant as shown.* Pounds per Square Inch.								
	10	15	20	25	30	35	40	45	50
Beaumont	426	526	608	678	743	799	852	......	....
Chapman No. 1	440	541	627	700	762	818	872	......	....
" " 2	547	667	765	853	938	1,020	1,098	......	....
" " 3	552	678	776	861	928	986	1,034	1,077	....
Chapman 3-way	371	458	531	593	648	701	748	792	834
" 4-way	363	442	513	578	630	680	725	767	806
Coffin Gate	497	607	701	780	850	913	974	......	....
" Compression	501	612	709	790	860	924	985	......	....
Corey 5-in	520	640	737	820	893	962	1,025	......	....
Glamorgan 4-in	449	550	636	709	773	831	886	......	....
Holyoke Gate, 4-in. bbl.	500	612	703	783	857	927	994	1,058	....
" " 6½-in. bbl.	545	668	760	844	921	992	1,048	......	....
Holyoke Compr'n No. 1	512	628	723	804	876	942	1,003	......	....
" Gate, 6-way	473	579	668	743	805	860	908	954	997
Ludlow	533	653	752	836	912	982	1,049	......	....
Mathews 5-in	576	712	815	903	984	.....	......	......	....
Mathews 4-way	465	565	633	688	724	762	796	827	857
Pratt & Cady	533	653	752	836	912	982	1,049	......	....

* Pressure can be equally well measured by tap at back of barrel opposite outlets.

TABLE V.

DISCHARGE OF TWO AND THREE OPEN HYDRANT BUTTS.



These figures apply only approximately to hydrants in general, because slight variations in construction, even in hydrants from the same shop, considerably affect the discharge from the open butt. The cuts of hydrants will suggest corrections, so that with good judgment results accurate within from 10 to 20 per cent. may, in general, be obtained.

NAME OF HYDRANT.	No. of Outlets Open.	DISCHARGE THROUGH OPEN BUTTS OF HYDRANT WITHOUT HOSE ATTACHED. (DIAMETER OF OUTLET EXACTLY 2¼ INCHES.) GALLONS PER MINUTE. Hydrant Pressure indicated while Stream is Flowing, by Gauge attached to Hydrant Barrel as shown.* Pounds per Square Inch. 5	10	15	20	25
Beaumont	2	....	904	1,158	1,327	....
Chapman No. 1	2	....	827	1,020	1,173	....
" " 2	2	....	974	1,197	1,377	....
" " 3	2	....	997	1,252	1,448	....
Chapman 3-way	2	....	876	1,074	1,228	1,329
" 4 way	2	....	868	1,068	1,212	....
Coffin Gate	2	....	904	1,158	1,327	....
Corey 4-in	2	....	1,170	....	....	....
Corey 5-in	2	....	1,091	1,322	....	....
Glamorgan 4-in	2	....	894	1,082	1,248	....
Holyoke Gate, 4-in. bbl	2	....	985	1,202	....	....
" " 6½-in. bbl	2	....	1,125	1,368	....	....
Holyoke Compression No. 1	2	....	1,051	1,278	....	....
" Gate, 6-way	2	....	942	1,152	1,326	1,466
Ludlow	2	....	1,008	1,200	1,364	....
Mathews 5-in	2	....	1,091	1,322	....	....
Mathews 4-way	2	....	890	1,089	1,238	1,341
Holyoke Gate, 6-way	3	992	1,388	....	....	....
Mathews 4-way	3	940	1,304	1,596	....	....

* Pressure can be equally well measured by tap at back of barrel opposite outlets.

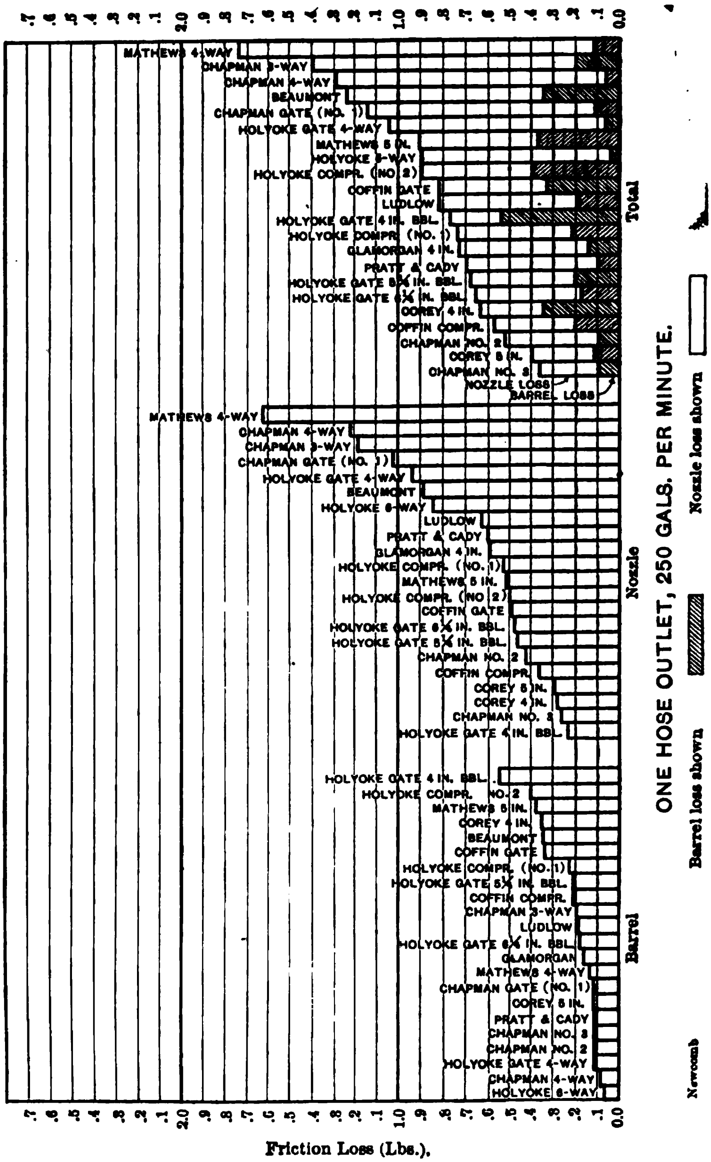

ONE HOSE OUTLET, 250 GALS. PER MINUTE.
Total
Nozzle
Barrel
Friction Loss (Lbs.).
Newcomb
Barrel loss shown
Nozzle loss shown
NOZZLE LOSS
BARREL LOSS

FIG. 47.

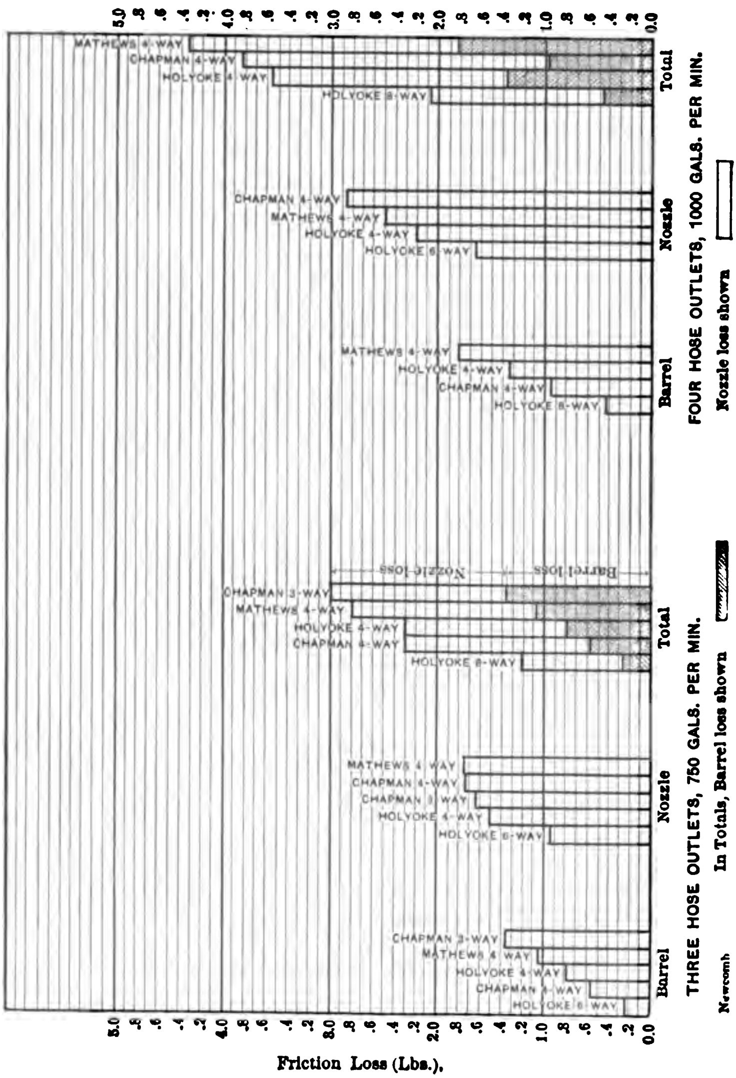

FOUR HOSE OUTLETS, 1000 GALS. PER MIN.
Nozzle loss shown
THREE HOSE OUTLETS, 750 GALS. PER MIN.
In Totals, Barrel loss shown
Total
Nozzle
Barrel
MATHEWS 4-WAY
CHAPMAN 4-WAY
HOLYOKE 4-WAY
HOLYOKE 6-WAY
CHAPMAN 3-WAY
Nozzle loss
Barrel loss
Friction Loss (Lbs.).
Newcomb

FIG. 48.

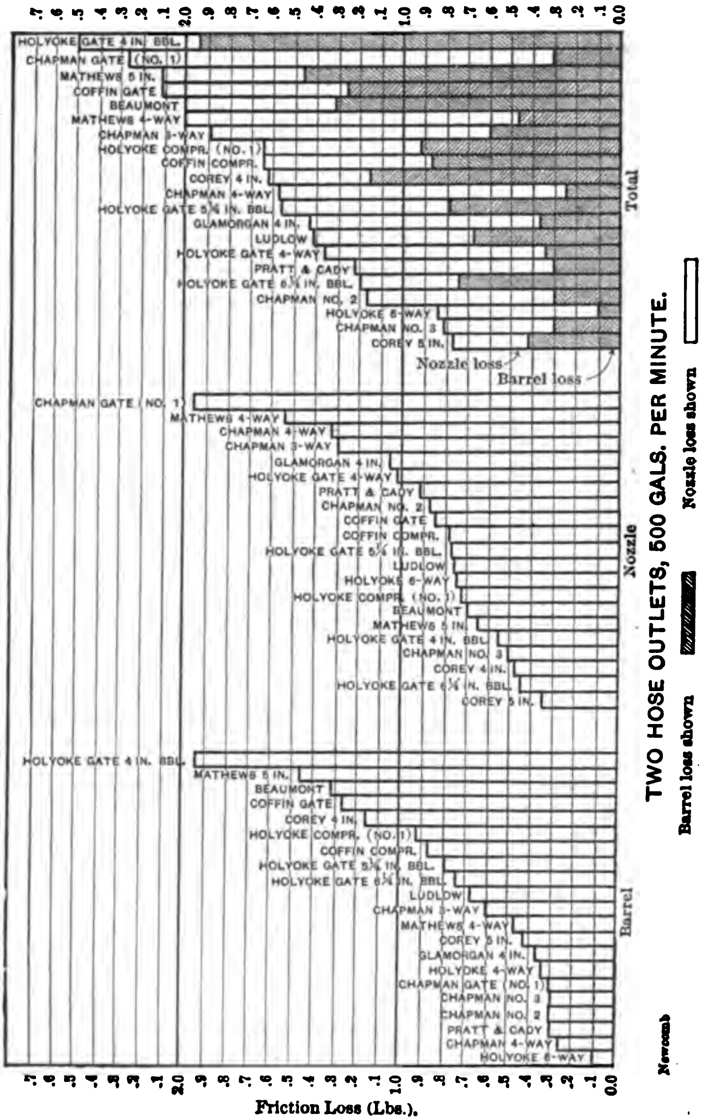

TWO HOSE OUTLETS, 500 GALS. PER MINUTE.
Barrel loss shown
Nozzle loss shown
Total
Nozzle
Barrel
Nozzle loss
Barrel loss
Friction Loss (Lbs.).
HOLYOKE GATE 4 IN. BBL.
CHAPMAN GATE (NO. 1)
MATHEWS 5 IN.
COFFIN GATE
BEAUMONT
MATHEWS 4-WAY
CHAPMAN 3-WAY
HOLYOKE COMPR. (NO. 1)
COFFIN COMPR.
COREY 4 IN.
CHAPMAN 4-WAY
HOLYOKE GATE 5¼ IN. BBL.
GLAMORGAN 4 IN.
LUDLOW
HOLYOKE GATE 4-WAY
PRATT & CADY
HOLYOKE GATE 6¼ IN. BBL.
CHAPMAN NO. 2
HOLYOKE 6-WAY
CHAPMAN NO. 3
COREY 5 IN.
Newcomb

FIG. 49.

DISCUSSION OF RESULTS.

The data and results being presented in full give ample chances for complete studies. Under these conditions detailed comparisons of the different hydrants have not been considered necessary or wholly desirable. A few general features may, however, be considered to advantage.

Barrel Loss. The best point of comparison for the two-way hydrants is with two hose outlets in use and 500 gallons per minute flowing, as this represents the full normal capacity of the hydrant. Similar full-capacity points should be taken in comparing the larger hydrants.

To make clear the composition of the so-called barrel loss, the following table has been made and shows about how much of this loss occurs in the barrels proper. The figures show at once that a large part of the loss must be in the gate and the sharp turn just beyond it, thus suggesting where to look for explanation for part of the large difference found. The distance from the center of the main gate to the center of the nozzles is, on the average hydrant, about 6½ feet. The following table gives approximately the friction loss in 6½ feet of clean, straight cylindrical pipe of the same smoothness as the inside of the average hydrant barrel.

FRICTION LOSS IN 6½ FEET. POUNDS PER SQUARE INCH.

Nominal Diameter of Pipe (Inches).	Gallons per Minute Flowing. 250.	500.	750.	1,000.
4	0.11	0.41	0.62	1.54
5	0.037	0.13	0.22	0.50
6	0.012	0.059	0.098	0.21
8	0.004	0.016	0.034	0.058

The table was made up from tests on ordinary new clean wrought-iron pipe with 25 per cent. added to the wrought-iron pipe figures for the somewhat greater roughness of the inside of the average hydrant casting. The 25 per cent. was an assumption based on general experience with pipes of various degrees of roughness.

Comparing on the pyramid diagrams hydrants having two 2½-inch outlets, the difference in barrel losses is seen to be large.

It is at once apparent that the 4-inch gate * and barrel are too small for a two-stream hydrant. A 4-inch barrel and a discharge of 500 gallons per minute mean a velocity of about 13 feet per second, so that a short length of barrel with the smoothest sort of a turn at the bottom develops an unreasonable loss, and this loss becomes still larger with the ordinary gate arrangement and sharp turn-bend.

Comparing further the hydrants which have about the same general dimensions, the difference in loss is considerable. This must be accounted for largely by differences in the design of the gate and the water passages in the immediate vicinity. Sharp corners, restricted sections, and sudden changes in the area of the passages all tend to produce eddyings, which use up pressure.

Nozzle Loss. As already stated, the nozzle losses are pure friction losses, full correction for velocity having been made. To compare the outlets themselves, looking at them as simple nozzles, the condition with one stream on and 250 gallons per minute flowing is the best point. Studying the losses and the cuts together, the effect of sharp, jagged corners at the outlets is immediately seen, and the very material reduction in loss by even a slight rounding of the outlet is apparent.

Considering the hydrant as a whole, by taking the conditions, with all of the outlets in use, it is seen that the average nozzle loss when all are in use is generally greater than with a single outlet in use. Separate tests on the two outlets of several hydrants showed a difference in loss with the same quantity flowing. This would account for a small part of the difference between loss with one outlet in use and with all outlets in use. Most of the difference is, however, undoubtedly due to the increase in choking and eddying effects at the top of the hydrant with the higher velocities. A part of this is due to reactions from the eddies at the outlets, and a part to the construction of the hydrant head.

The somewhat high losses with the Beaumont hydrant, considering the rounding outlets, is probably due to the fact that

* It was desired to have tests on some 4-inch-barrel hydrants to make the data complete, though most of the manufacturers would in general furnish larger barrels for two outlets. The 4-inch hydrant is, however, occasionally used.

the gage connection was necessarily several inches below the outlet, so that there was considerable length between the gage connection and the outlet, in which length some ordinary friction loss would occur.

Total Losses. The total-loss pyramid shows the relative obstruction caused by the different hydrants taken as a whole. The part of this due to the barrel has been cross-hatched and the part due to the nozzle left white, thus showing at a glance the relation of the two factors making up the total loss.

It is desirable that the waste of pressure through a hydrant should be as small as it is practicable to make it. In high-pressure systems the losses found for the average hydrants are perhaps tolerable, but in lower-pressure systems — and many systems having a nominally high pressure become low under heavy drafts — every avoidable loss is objectionable. In the hydrants without independent gates a simple rounding of the corners of the core at the outlet will make a material improvement in the nozzle losses. Reduction of loss for independent gate hydrants is more difficult, but some improvement is probably possible without serious trouble. The fact that some makers have found out how to reduce the barrel losses, so called, to comparatively small amounts is good working ground for improvements in those hydrants now having rather large losses.

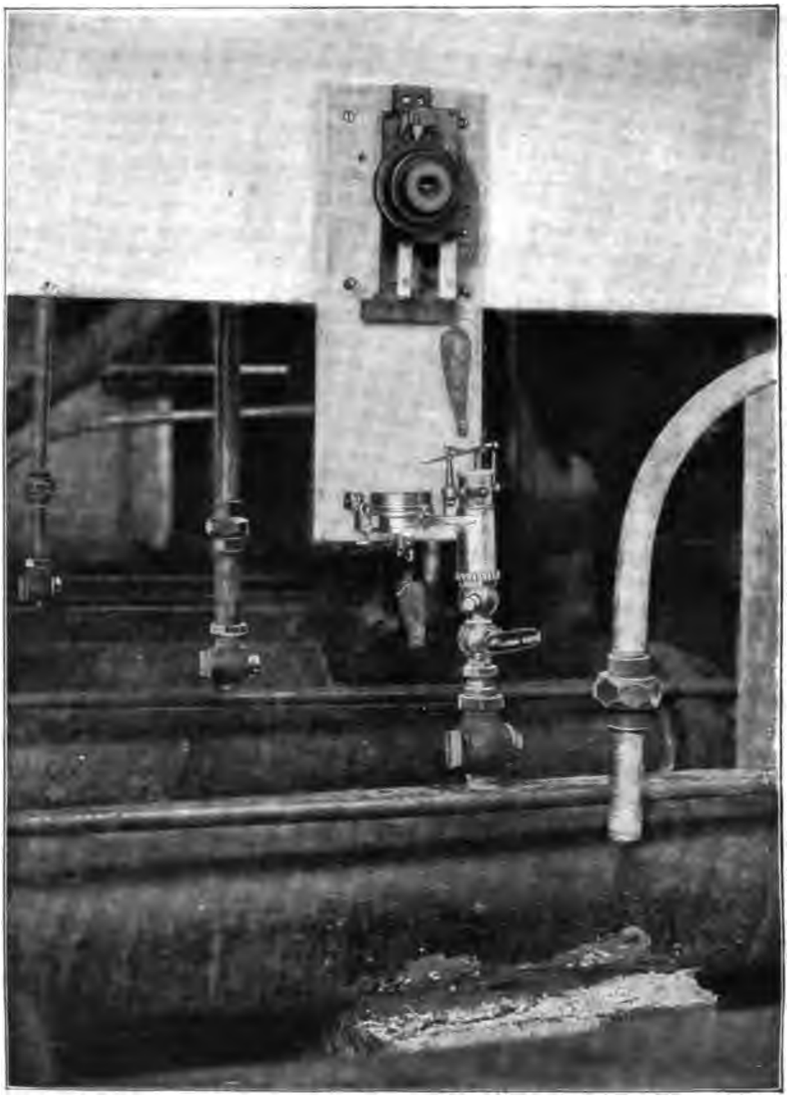
It is not to be understood that this friction loss is the criterion for a perfect hydrant. Certainty of action under all conditions is of the greatest importance, but, other things being equal, the hydrant having the smallest total friction loss when working at its full capacity is the best.

WATER-HAMMER TESTS.

To get some measure of the water-hammer effect, caused when a hydrant is quickly shut down, the following apparatus was devised:

An indicator was attached to the connection in the 6-inch hydrant inlet which had been used by the U-tubes. The drum of this indicator was operated by clockwork in the manner shown in Plate III, and was so adjusted as to revolve once in from three and a half to four minutes. A small weight and cord kept

PLATE III.



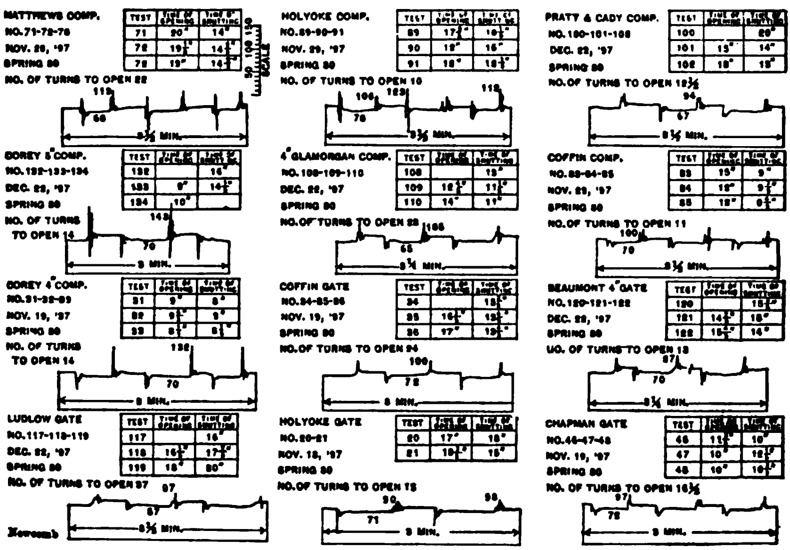
APPARATUS FOR TAKING WATER-HAMMER CARDS.

the pencil in contact with the paper during the taking of a card. Plate II, Fig. 2, also shows the rig on a smaller scale.

Two lines of hose were taken from the hydrant under test to the meter nozzle, and the hydrant gate opened wide. A 1¾-inch nozzle was used and the pressure set at about 43 pounds by adjusting the gate on the inlet pipe at the entrance to the building. This gave a discharge of approximately 600 gallons per minute, which was considered a fair rate of flow for these tests.

At a given signal the indicator cock was opened, the clockwork set in motion, and time taken. After running steadily for about one fourth of a minute the hydrant valve was quickly closed; that is, it was closed as quickly as an active man could close it, using an ordinary hydrant wrench.

As soon as steady conditions were restored, the valve was as quickly opened again. This was repeated two to three times during the time that drum of indicator was in motion. Any variation of pressure caused by this closing or opening of the valve was recorded on the card. The time occupied in closing, and also



* Gate went hard near end of closing, preventing normal water-hammer action.

Fig. 50. Water-Hammer Cards.

in opening, was taken by a stop-watch, so that some comparison can be made between the treatment given any one hydrant and another. Sample cards from the various tests have been picked out, grouped, and directly reproduced in Fig. 50. In getting this reproduction the delicate lines made by the pencil point of the indicator were carefully gone over with ink so as to get a card which could be photographed.

This method of measuring cannot show just what the actual pounds rise of pressure in any particular case would be, as this depends on the arrangement of piping supplying the hydrant, and the drafts of water in the system independent of the hydrant draft. It does, however, give a rough means of comparing the different hydrants.

The cards show that the gate hydrants give generally considerably less water-hammer than the compression type.*

It was stated in explanation of the large hammer effects found in one of the special type of compression hydrants that firemen demand a hydrant which will give the full pressure at the earliest possible moment, so that a quick movement was purposely designed. It is firmly believed that in the long run it will be very much better to insure the safety of water mains by avoiding heavy water-hammer effects than to gain a few seconds of time at the risk of crippling the distributing system, very likely at the critical point of a fire.

In several of the compression hydrants a vibrating effect will be noticed during the opening of the valve. This is apparently due to a chattering of the valve, and produces a rather undesirable water-hammer, as it is a series of quick, sharp blows.

CONSTRUCTION, STRENGTH, ETC.

Time prevented carrying on this part of the work as thoroughly as was desired, so that only partial results were obtained for

* The comparatively small hammer shown by the Coffin Compression is probably explained by the special double-beat valve, which is designed to give a more gradual closing than is ordinarily obtained with the compression type of gate.

The small hammer shown by the Pratt & Cady Compression is probably largely due to the fact that, when near the point of closing, the stream began to go hard, preventing a quick shutdown. The results are, therefore, not fairly comparable with the other hydrants. In the other hydrants the force required to open and close appeared about normal.

some of the hydrants, while on most of them a considerably further study of construction and general features would have been desirable. What data were obtained is shown in Table VI, about which the following explanations may be made:

Column 3. The inside volume of the hydrant is the volume between the main gate and the caps on the nozzles. This was obtained by filling the hydrant completely full of water and computing the volume from the weight of water.

Column 4. The time to drain the hydrant was taken from the instant the main gate was closed. Facts which developed as the tests progressed from the ordinary handling of the hydrants tended to show the desirability of having positive-motion drip-valves. Two of the hydrants had not positive drips, and in both of these the drips got out of order and failed to close when the main valve was open. The importance of having an absolutely reliable drip-valve, so as to reduce the chances of freezing to a minimum, must be apparent to every one.

Columns 5 and 6. The hydrostatic tests were made with an ordinary high-pressure hand pump, which is shown at one corner of the room in Plate II, Fig. 2. The aim was not to break anything, but to see how the hydrant would act with a considerable increase of pressure above the normal. Table VI shows the results in full.

Column 7. A broken or twisted valve stem is not an uncommon result of the excitement of a large fire. Sometimes a hydrant sticks, or a mistake is made in the direction to turn for opening or closing. Often in such cases, if one man cannot start the hydrant, two or more men take hold. In this connection it is somewhat surprising that so far as known no one has yet made a hydrant which is not liable to serious damage if a forcible attempt is made to turn it in the wrong direction, either opening or closing; something accomplishing what the ratchet on a stem-winding watch accomplishes seems possible and greatly preferable to the simple limit of breaking strength. Such a device might also give the fireman immediate evidence that he was wrong, thus saving time. A hydrant cannot be expected to stand unlimited abuse, but to get some idea of the ability of the hydrants to withstand such usage the following tests were made: Two ordinary men

TABLE VI.—CONSTRUCTION AND STRENGTH OF HYDRANTS.

1	2	3	4		5		6		7
NAME OF HYDRANT.	Weight of Hydrant.	Inside Volume of Hydrant.	Time Required to Drain.		HYDROSTATIC TEST OF MAIN VALVE.		HYDROSTATIC TEST OF HYDRANT BARREL.		Result of Test of Valve Stems.
					Pressure Put on.	Result.	Pressure put on.	Result.	
	lbs.	cu. ft.	m.	s.	lbs.		lbs.		
Beaumont	290	0.69	2	30	180	Valve tight.	300	Drip leaked very little	Stems twisted off.
Chapman No. 1	435	1.39	7	30	180	Pressure dropped in ½ min. 80 lbs.	150	Caps leaked.	Stem twisted out of shape.
" No. 2	425	1.44	7	15					
" No. 3	734	2.29	5	11					
Chapman 3-way	577	1.63	7	01					
" 4-way	580	2.34							
Coffin Gate	467	1.59	......	......	180	Pressure dropped in 1 min. 80 lbs.	240	Caps leaked.	Not injured.
" Compression	506	1.44	7	30	180	Pressure dropped in 1 min. 75 lbs.	280	" "	Stem strained, but not broken.
Corey 4-in	418	1.55	2	20	180	Pressure dropped in 1 min. 80 lbs.	200	" "	
" 5-in	560	2.24	3	40	180	Pressure dropped in 40 secs. 80 lbs.	300	" "	Not injured.
Glamorgan 4-in	531	1.22	2	05	180	Valve tight.	280	" "	Top of stem broken off.
Holyoke Gate, 4-in	356	1.02							
Holyoke Gate, 6½-in	500	2.16	9	00	180	Pressure dropped in 1 min. 80 lbs.	300	Caps leaked.	Stem twisted off.
" Compression No. 1	669	1.20	4	30	180	Pressure dropped in 1 min. 80 lbs.	220	" "	Bottom of hydrant pushed out.
" " No. 2	538	0.77							
" Gate, 4-way	580	2.24							
" " 6-way	......	......	31	06					
Ludlow	497	1.87	3	40	180		280	Caps leaked.	Stem twisted out of shape.
Mathews 5-in	750	1.42	5	30	180	Pressure dropped in 50 secs. 80 lbs.	280	Flange at bottom leaked	Top of stem broken off.
" 4-way	767	1.50							
Pratt & Cady	688	2.28	15	00	70	Valve leaked badly.	220	Caps leaked.	Yoke in bottom of hydrant broken.

were instructed to open each hydrant, using the regular hydrant wrench, which is 17 inches long, exerting their maximum strength in an effort to open the hydrant beyond its natural limit. If no injury resulted they closed the hydrant, exerting again their maximum strength after the hydrant was completely shut.

These tests, therefore, took the strength of two ordinary men using a wrench of definite length as the measure of the force applied. It is not exact in any way; but gives some results which, in a practical way, are somewhat useful.

In most instances some injury was done to the hydrant, the stem generally being the point to give way, though in one case the bottom of a hydrant was actually pushed out by attempting to open it beyond its natural limit.

Durability and Repair. Time did not give a chance for any complete tests on the durability of the working parts of the hydrant, but starting with the assumption that a hydrant might be opened on an average ten times a year, and should be good for a service of twenty years, each hydrant was opened and closed two hundred times. No special derangement of wear resulted, except in two cases, in which the stuffing-box nut on top of the hydrants showed a tendency to work loose.

In a number of the hydrants the design has been made with the idea of facilitating repairs. In some cases this resulted in considerable restriction to the water ways. It is believed that in most cases, by keeping the desirability of free water ways in mind, ability to make quick repairs can be combined with smooth, free waterways. In this connection the friction-loss tests will be of value in showing what can be done and what should be avoided.

METER TESTS.

As previously stated, the two large meters used in the open-butt tests were calibrated by the nozzles, the quantities by the nozzles being assumed to be correct. This calibration work was done in connection with the regular tests, but has been tabulated independently, and the data in full are given in Tables VII and VIII. From these data a curve was plotted for each meter, with nozzle readings for one coördinate and meter readings for the

other (see Fig. 51). From this curve the corrected meter readings were taken directly in working up the open-butt tests.

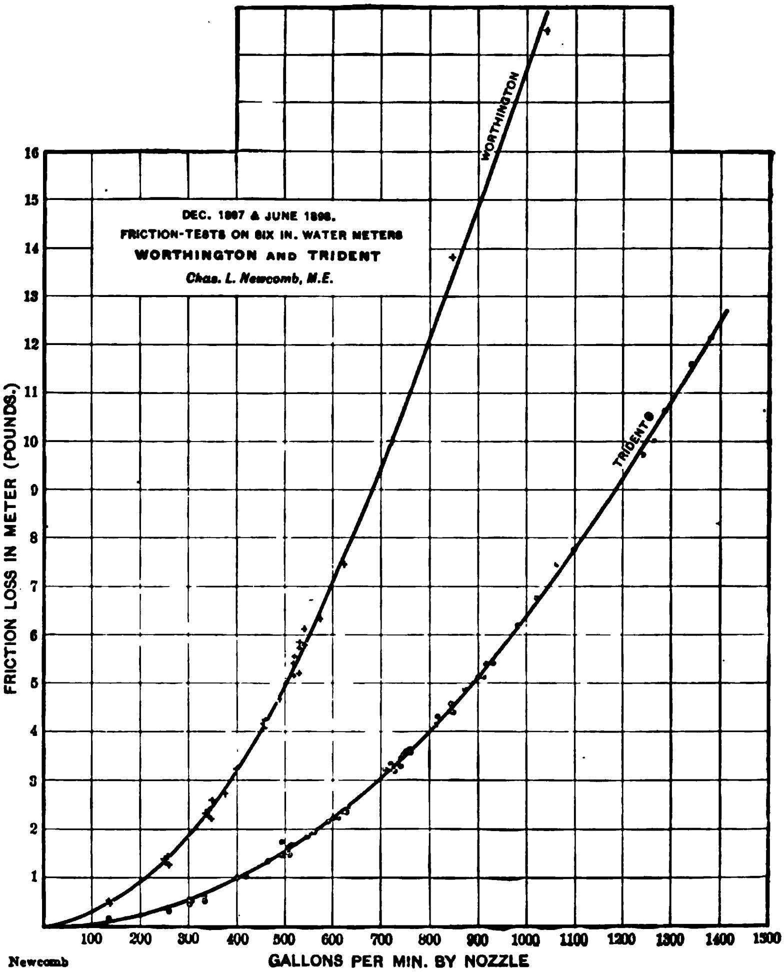


FIG. 51.

The arrangement of the apparatus gave an excellent opportunity to determine the obstruction to the flow of water; that is, the friction loss caused by the meters. As this may become an

important feature where handling large quantities of water, and as data on large meters with high rates of flow are not very complete, a few tests were made to determine this loss. The method of testing followed was similar to that employed in the series of meter tests reported by Mr. E. V. French in the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.* A gage connection

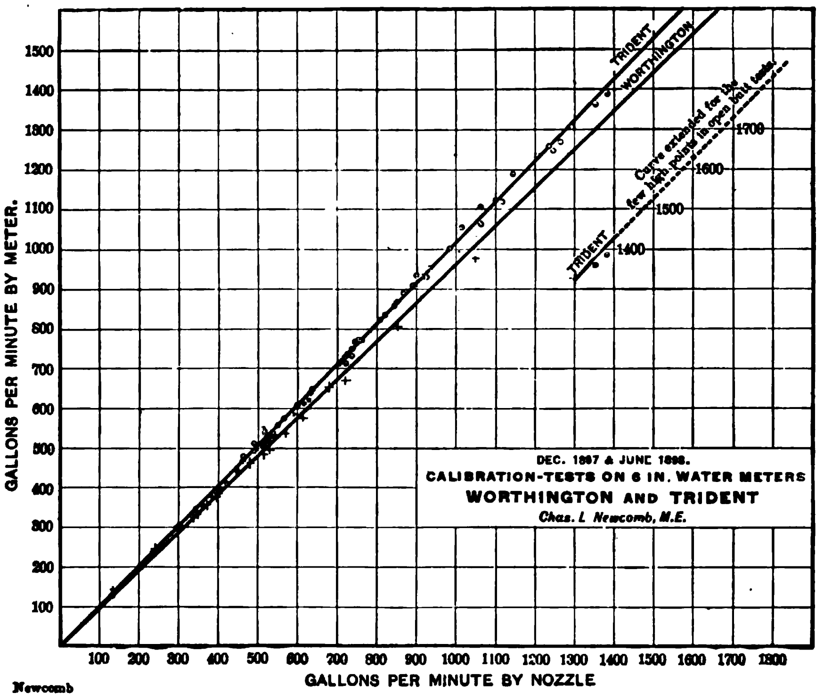


FIG. 52.

was tapped into the 6-inch pipe at each side of the meter and a short distance from it, the connection being arranged the same as those at the inlet pipe of the hydrants. Between these two connections a mercury U-gage was attached, and the friction loss caused by the meter with various rates of flow was read

* "Losses of Pressure Caused by Meters in Factory Fire Supplies," JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, vol. XXII, No. 2.

directly from this gage. The loss in the short lengths of the 6-inch pipe between the gage connections and the meter is included in the meter loss, as it was too small to be of practical importance. These data also appear in full in Tables VII and VIII, and the results have been plotted on Fig. 52, with the gallons per minute as one coördinate and the losses in pressure in pounds as the other.

The question is sometimes raised as to what would happen if the moving parts of a meter became blocked, an accident which may happen where a fish-trap is not provided with the meter, and which is a possibility under some conditions even where a fish-trap is used. After the hydrant tests were completed, a few experiments in this line were made with the Neptune meter, the owners having kindly consented that any sort of tests should be made with it, regardless of the results. The cover was removed and wooden wedges inserted, so as to hold the disk in various positions. It was found that it could be blocked so that almost no water could go through it, and that any degree of obstruction between this and a free opening could be obtained. With the meter blocked in various positions, full water pressure was turned on behind it to see if anything would be broken or sprung; and when in the position where practically no water got through the meter, the pressure warped the disk, though not enough to appreciably increase the flow of water.

TABLE VII.

Tests on 6-inch Worthington Water Meter.

1	2	3		4	5	6	7	8	9	10
Test No.	Date of Test.	Duration of Test.		Diam. of Nozzle. Inches.	Pressure at Nozzle. Corrected Pounds.	Gallons per Minute by Nozzle.	Total Cubic Feet by Meter.	Gallons per Minute by Meter.	Diff. in Gals. per Min. Nozzle as Standard (6—8).	P'ds Loss between Gauge Con'ctions eq'ls Meter Loss.
		m.	s.							
488	Dec. 10, 1897	11	01⅖	¾	66.70	135	200	135	0	
489	"	11	44⅕	1⅛	46.49	255	400	255	0	1.29
490	"	11	29	1¼	53.18	340	500	326	+14	2.23
491	"	10	01⅕	1½	24.14	458	600	448	+10	4.24
492	"	10	11⅗	2	17.44	518	700	514	+ 4	5.41
493	"	10	24	1¼	64.60	375	500	360	15	2.75
494	"	10	42⅘	1½	30.34	514	700	488	26	5.18
495	"	10	08⅕	1½	44.63	623	800	590	33	7.45
496	"	10	55⅗	2	33.84	722	1,000	684	38	10.00
497	"	10	12⅘	2¼	16.87	848	1,100	806	42	13.80
498	"	10	40⅗	2¼	25.53	1,044	1,400	981	63	18.50
499	"	11	12	¾	65.66	134	200	134	0	0.50
500	"	11	52⅕	1⅛	46.07	254	400	252	2	1.31
501	Dec. 11, 1897	11	38⅘	1¼	51.77	336	500	321	15	2.32
502	"	13	26⅘	1½	23.87	457	800	445	12	4.17
503	"	10	12⅘	2	17.23	516	700	512	4	5.55
509	"	11	11	¾	65.68	134	200	134	0	0.50
510	"	11	53⅕	1⅛	45.73	254	400	252	2	1.40
511	"	11	32⅕	1¼	52.96	340	500	333	7	2.29
512	"	10	06⅕	1½	23.95	457	600	444	13	4.18
513	"	10	02	2	18.36	531	700	522	9	5.85
519	Dec. 13, 1897	11	11	¾	65.7	134	200	134	0	0.50
520	"	11	49⅘	1⅛	45.94	254	400	253	1	1.41
521	"	11	30⅗	1¼	53.25	340	500	324	16	2.39
522	"	11	47⅕	1½	23.65	455	700	444	11	4.18
523	"	11	28⅕	2	18.3	530	800	522	8	5.75
524	"	11	15	¾	64.78	133	200	133	0	.54
525	"	11	52⅕	1⅛	46.00	254	400	252	2	1.45
526	"	11	33	1¼	53.08	340	500	324	16	2.26
527	"	10	06⅗	1½	23.86	456	600	443	13	4.08
528	"	11	18⅘	2	18.69	537	800	529	8	5.80
591	Dec. 16, 1897	11	19	2	18.87	540	800	529	11	6.11
592	"	11	01⅕	1½	14.00	350	500	341	9	18.60
593	"	11	34⅕	1½	18.2	398	600	386	12	3.24
594	"	11	22⅘	1½	26.9	485	700	462	23	4.65
595	"	10	28⅘	1½	32.0	528	700	498	30	5.20
596	"	11	06⅕	1½	37.2	570	800	539	31	6.31
609	"	5	56	2	9.76	388	300	378	10	......
610	"	5	45⅗	2	29.76	578	500	650	28	......
611	"	11	45	1½	18.23	398	600	382	16	......
612	"	11	21⅗	1½	27.04	485	700	461	24	......

TABLE VIII.

Test on 6-inch Trident Water Meter.

1	2	3		4	5	6	7	8	9	10
Test No.	Date of Test.	Durat'n of Test.		Diam. of Nozzle. Inches.	Pres're at Nozzle Cor'ted Lbs.	Gallons per Minute by Nozzle.	Total Cubic Feet by Meter.	Gallons per Min. by Meter.	Diff. in Gals. per Min. Nozzle as Standard (6-8).	Pounds Loss between Gauge Connections Equals Meter Loss.
		m.	s.							
875	June 2, 1898.	5	06⅗	⅞	66.04	185	90	180	+ 5	....
876	" " "	5	02⅖	1⅛	44.41	250	170	247	+ 3	....
877	" " "	5	09⅘	1¼	50.31	332	230	328	+ 4	....
878	" " "	5	01⅘	1¾	24.52	463	320	471	− 8	....
879	" " "	5	00⅘	2	16.98	511	360	530	− 19	1.68
880	" " "	4	59⅘	1¼	41.62	301	200	296	+ 5	0.47
881	" " "	4	57⅘	1¾	29.53	507	340	507	0	1.50
882	" " "	4	59⅘	1¾	44.52	623	420	619	+ 4	2.82
883	" " "	5	01⅘	2	33.26	708	490	723	− 15	3.20
884	" " "	5	01	2½	15.52	807	560	826	− 19	4.10
885	" " "	1	59⅘	2½	19.60	916	250	929	− 13	5.40
886	" " "	1	59⅘	2	35.35	738	200	741	− 3	3.30
887	" " "	1	59⅘	1¾	39.99	590	160	592	− 2	2.16
888	" " "	2	59⅘	1¾	18.43	400	160	395	− 5	1.02
889	" " "	2	12⅘	1¼	41.52	300	90	301	− 1	0.57
890	" " "	2	02⅘	1¾	29.29	506	140	507	− 1	1.53
891	" " "	2	02⅘	1¾	48.00	612	170	615	− 3	2.21
892	" " "	2	02	2	33.56	720	200	727	− 7	3.23
893	" " "	2	02⅕	2½	15.72	819	230	835	− 16	4.30
894	" " "	2	05	2	19.47	549	160	561	− 12	1.86
895	" " "	2	05⅘	2	34.74	731	210	745	− 14	3.46
896	" " "	2	05⅘	2½	17.85	873	250	893	− 20	4.89
897	" " "	2	00⅘	2½	22.65	982	270	1,001	− 19	6.18
898	" " "	2	31	2 & 1	23.78 24.12	752	260	772	− 20	3.57
899	" " "	1	31⅘	2 & 1	34.05 34.87	898	190	929	− 31	5.10
900	" " "	1	38⅕	2½ & 1⅛	18.32 22.07	1,063	230	1,104	− 41	7.49
901	" " "	1	30⅕	2½ & 1¼	20.67 21.25	1,156	240	1,194	− 38	8.77
902	" " "	2	39⅘	2½ 1⅛ & 1⅛	17.50 24.42	1,237	330	1,260	− 23	9.67
903	" " "	2	30⅘	2½ 1⅛ & 1⅛	13.98 19.89	1,109	330	1,126	− 17	8.29
904	" " "	1	32	2½ 1¼ & 1¼	....	1,277	270	1,315	− 18	10.90
1,197	June 21, 1898.	3	18⅘	¾	65.31	134	60	136	− 2	0.14
1,198	" " "	3	09⅘	1⅛	47.16	258	110	260	− 2	0.32
1,199	" " "	3	05⅘	1¼	51.51	334	140	338	− 4	0.66
1,200	" " "	3	07⅖	1¾	24.61	463	200	478	− 15	1.33
1,201	" " "	3	05	2	16.65	507	230	534	− 27	1.66
1,202	" " "	3	13⅕	1¼	41.47	302	130	302	0	0.55
1,203	" " "	3	05⅘	1¾	28.34	494	210	508	− 14	1.47
1,204	" " "	3	02⅕	1¾	45.36	620	260	639	− 10	2.31
1,205	" " "	3	02	2	34.06	725	300	740	− 15	3.20
1,206	" " "	3	02⅖	2½	16.59	843	350	861	− 18	4.58
1,207	" " "	3	03⅘	1¾	19.14	417	170	416	+ 1	1.05
1,208	" " "	2	05⅘	1¾	41.10	600	170	608	− 8	2.22
1,209	" " "	3	05⅘	2	37.63	761	320	775	− 14	3.57
1,210	" " "	3	04⅘	2½	20.21	930	390	949	− 19	5.40
1,211	" " "	3	07⅘	2	20.44	561	240	574	− 13	1.97
1,212	" " "	3	08⅘	2	35.87	745	310	759	− 14	3.49
1,213	" " "	3	08⅘	2½	18.49	889	370	906	− 17	5.03
1,214	" " "	3	01⅘	2½	25 53	1,028	430	1,068	− 40	6 77
1,215	" " "	3	14	1¼	42.27	307	130	301	+ 6	0.56
1,216	" " "	3	00⅘	1¾	27.99	494	200	498	− 4	1.73
1,217	" " "	3	01⅘	1¾	45.59	630	260	642	− 12	2.44
1,218	" " "	3	03⅘	2	33.61	720	300	732	− 12	3.30
1,219	" " "	3	01	2½	16.86	849	350	868	− 19	4.40
1,220	" " "	2	30⅘	2 & 1	23.83 26.32	750	260	775	− 16	3.60
1,221	" " "	2	34⅘	2 & 1	34.23 38.33	910	320	939	− 19	5.13
1,222	" " "	2	31⅘	2½ & 1⅛	19.11 27.30	1,100	360	1,126	− 26	7.77
1,223	" " "	2	38⅘	2½ & 1¼	22.86 29.22	1,243	430	1,256	− 13	9.70
1,224	" " "	2	31⅘	2½ & 1⅜	22.81 24.95	1,264	430	1,275	− 11	10.01
1,225	" " "	2	31	2½ 1⅛ & 1⅛	18.91 26.90	1,292	440	1,308	− 16	10.60
1,226	" " "	2	31⅘	2½ 1⅛ & 1⅛	20.56 29.57	1,346	460	1,364	− 18	11.56
1,227	" " "	2	31⅘	2½ 1¼ & 1¼	19.56 25.32	1,387	470	1,391	− 4	12.13
1,228	" " "	2	30⅘	2½ 1¼ & 1¼	11.45 15.25	1,065	360	1,073	− 8	7.47

DISCUSSION.

President John C. Whitney. This paper of Mr. Newcomb, which represents an extraordinary amount of thought and labor, is now open to discussion.

Mr. Newcomb, I should like to inquire what period of time was necessary in order to bring about these results which you have tabulated.

Mr. Newcomb. You mean, what period the tests covered?

The President. Yes.

Mr. Newcomb. Something like a year and a half, although they were not carried on continuously during that time.

The President. Mr. Stacy, we should like to hear from you on the subject of fire hydrants, in reference to this paper especially.

Mr. George A. Stacy.* Mr. President, I don't know as I am prepared. I ought to be; we have had the paper long enough.

The President. You don't need to be.

Mr. Stacy. It brings out one point, I think, that in the number of years we have been constructing hydrants there hasn't been much of an effort made to reduce the friction in the hydrant by giving it easier water ways, except in two or three instances.

There are various points about hydrants that are not touched on, as this paper pertains largely to the important question of friction losses.

I think that this paper brings out the fact that hydrants are made with a large factor of safety. I know of a place where they have used an abnormally long hydrant wrench and a 3-foot piece of pipe. I asked the boys what they were doing with it, and they said, "We open our hydrants with that." They said, "Two fellows get hold of that, and if they can't open it, three of us get hold of it." [Laughter.] This was a number of years ago. At the present time they do not have that trouble. I make that statement just as they made it to me, and perhaps they made it a little strong. I know they had considerable trouble in opening hydrants, and they used considerable power; but I do not think the trouble was altogether with the hydrant construction.

Of course we have often seen a fireman try to open a hydrant

* Superintendent of Water Works, Marlboro, Mass.

the wrong way, and I don't think that is anything remarkable. A man in the volunteer fire department jumps out of bed and rushes to a fire, and he forgets which way the hydrant opens, — in the excitement of the moment he doesn't stop to think. But it shows that it generally takes more than one man to break the hydrants that are made to-day.

Another thing is the mechanical construction of the hydrants. I think there is a wide range of workmanship in the different hydrants. My experience is that there is lots of work done in the foundry that ought to be done in the machine shop on a good many hydrants. I have found, in my experience, hydrants where the fits, as I call them, were made in the foundry with cores that should be made in the machine shop with proper tools.

Speaking of the drip, it seems to me that we haven't made a great deal of progress and improvement. If we could have a drip that we could control from the surface, and actually know that it was working, and be able to close it permanently if we desired to, it would be an improvement in many localities.

And in regard to the frost case of hydrants: It seems to be considered by some that the function of the frost case is to protect the hydrant from frost. I never had that idea. The frost case is, as I understand it, for the purpose of keeping the frost from heaving the hydrant posts. We have hydrants made by some of our manufacturers where the frost case has no movement up or down; you can only revolve it around. I have got a few of them, and under these conditions the frost case is useless and iron thrown away.

This paper has brought out the necessity of better construction in the water ways of hydrants in order to get the maximum efficiency. It has also demonstrated that the hydrants that are in the market stand up to the rough usage that they sometimes get remarkably well.

We often hear of a non-freezing hydrant, because the drip is on a level or below the inlet pipe; this is not true under many conditions. I have perhaps six where the drip is a menace to the hydrant; they have to be plugged to keep the ground water out. I have one hydrant that is set under a bank on the sidewalk in the city, and in the spring, before the frost is out of the ground, in

March or the last of February, and sometimes during the winter, if the drip is open, the water will flow out of the nozzle from the water in the ground. Perhaps some of you have had that experience. Under these conditions, a drip that could be plugged without digging up the hydrant would be useful. I will say that the situation is where a bank 8 or 9 feet high is back of the hydrant, where the street has been cut down.

I think we should be more particular as to the mechanical construction, that is, the machine work that is put into the hydrant; I believe it pays. I have some hydrants that I think are as finely made as is required in that kind of work; they have been in the ground twenty-four years and a large per cent. of them have never cost a cent for repairs, and I have others that are not so well constructed, though just as strong, that have caused more or less trouble and expense.

I confess that I am not able to go into this thing very closely; there are others here who perhaps have studied this more than I have. It is a very interesting and instructive paper. I think that hydrant is something that can be improved, and it is up to us to pick out the points and tell what we want.

In regard to the nozzles, it has been the custom for a large majority of manufacturers to lead them in. I have hydrants that have never given me any trouble that are so constructed, and I have some that have caused considerable trouble and expense. I would not buy a hydrant of any kind to-day if the nozzle was not screwed into the barrel, unless forced to do so. Some object to that, saying that it may get loose. I think that could be prevented. I would require that every nozzle should be screwed in and so fastened that I could take it out, to replace or repair it; the same as any bolt or screw, and with as little trouble. I think we are all under great obligation to the City of Holyoke Water Board, who promoted, and to the men who assisted in making, these tests.

THE PRESIDENT. We should like to hear from Mr. McInnes.

MR. FRANK A. MCINNES.* I don't know, Mr. President, that I have much to say that is valuable. I feel very sure, however, that discussion on the fire hydrant is time well spent, as its full

*Assistant City Engineer, Boston, Mass.

share of blame has not always been given to the hydrant when needed pressure was not forthcoming. Unfortunately a hydrant of poor design fails when it is most needed; with a small flow and under ordinary conditions the loss, through its inefficiency, is perhaps unnoticed, but when the big fire comes along and a large flow is demanded, the test and the failure come; then valuable pressure in the main is simply wasted, thrown away in the hydrant; particularly is this true in the case of hydrants with steamer connections fitted with independent valves. One who has actually tested the friction loss in independent valves will quickly realize that an undue loss, an altogether inexcusable loss, may easily occur.

In Boston the conditions are somewhat severe. Two engines pumping 1 100 gallons per minute each, and nine pumping 750 gallons each, respond, with other smaller engines, to alarms down-town; these demands call for a hydrant capable of delivering about 2 500 gallons per minute without excessive loss, with 1 100 gallons per minute through at least one outlet, and that must be an independent valve outlet. (I think steamer outlets, particularly in city practice, should always be fitted with independent valves.)

To meet these conditions we started at the main, making the pipe leading to the hydrant 8 inches in diameter; we then considered the hydrant pot and made a new design for it to ease the flow as much as possible; then came the hydrant barrel, which was made practically 8 inches, with an ample water way at the bottom around the main valve; at this point our troubles began, because of the independent outlet through which we had to take 1 100 gallons per minute, without undue loss of head. Four different valves were designed and carefully tested with Bourdon gages, using the nozzle as a meter; that adopted is a simple gate valve inside the hydrant, working up and down in front of the outlet. The guides for the valve are cast in the shell of the hydrant itself, and when the valve is open there is absolutely nothing in the water way; it is entirely free.

Throughout the whole hydrant design we have tried to consider every little detail, avoiding sharp corners, projections, etc., wherever possible. For results, we get a total loss in the 4½-inch

valve on steamer outlet of 5 pounds, with 1 100 gallons per minute flowing; of this amount about 2 pounds represents the actual friction loss, the remainder, of course, being the head required to give the velocity. In the hydrant barrel and pot, with a flow of 2 500 gallons per minute, the loss was about 3½ pounds. We have concluded to be satisfied with these results, for the present at least, and consider that we have a hydrant in which the losses, under ordinary conditions, are almost negligible. In view of the fact that the demands of an adequate fire service require a much larger expenditure for main pipe than would be necessary for domestic service only, it is well worth while to be sure that the hydrant lead is large enough and that the hydrant itself is efficient.

THE PRESIDENT. We should like to hear from Mr. Brooks.

MR. EDWIN C. BROOKS.* I agree very thoroughly with what Mr. McInnes has said in this respect; that I think hydrants have been made, not with the care that they should have been made, not with the idea thoroughly in mind that the object was to get the water from the main to the nozzle of the hydrant with the least possible loss. And I think that it has been largely a matter of cost. We all know that when you get your figures for hydrants, as a general proposition the low figure wins; and that has been too much in evidence, not only with hydrants, but with other water-works appliances.

I wish that this Association might set the pace for not only a better hydrant in the way of construction, but a hydrant that was made with a thorough conception of all the abuse that it is liable or possible to get while in use.

Now we have in our city every department, I think, with the exception of the cemetery department, or the almshouse, using hydrants *ad lib.:* The sewer department is using hydrants for flushing sewers and for all kinds of construction work; the street department is using hydrants for filling roller tanks and many other uses; and the park department use hydrants for filling their barrels for the moth and bug mixtures; and so it goes. As a result we find it very hard to fix the responsibility for broken hydrants. Notwithstanding that we find a hydrant with a screw

* Superintendent of Water Works, Cambridge, Mass.

whose office it is to raise the valve bent in the form of an "S," the man who used it last swears that they tried to open it the right way. [Laughter.] When you are up against anything of that kind, the only solution of it is to make the screw and the rod so strong that they can't bend them. I think it was one of the early Boston superintendents, Mr. Jones, who said that the measure of the strength of a 6-inch gate spindle was not what was required to operate the gate, but what was required to stand the strength of two good burly men on the end of a long gate wrench.

Now, when it comes to that, gentlemen, your factors of safety have got to be modified considerably. I was interested in hearing Mr. Newcomb read of a hydrant bottom being pushed out. We recently had a case of that kind, yet the men swore that they were closing the hydrant in place of opening it; that the valve wasn't down; it was hardly clear how the bottom could come out, but nevertheless it did.

An amusing incident occurred in a damage suit for throwing water down a man's chimney from a broken hydrant and damaging the ceilings and carpets in his rooms and so forth. That occurred with one hydrant which you probably know very well, which has a composition bushing at the top of the hydrant in which the hexagonal rod fits, and the flange on this bushing keeps the bushing from coming out, being put in from below. That flange broke off, the rod went up through the top of the hydrant, and a 1½-inch stream went up into the air; the wind blew it over into this man's chimney, it went down his chimney, out of his fireplace, and ruined his ceilings and his carpets. Now the moral from that is, not to have fireplaces, I suppose. [Laughter.]

But seriously, I think that if all the combined talent was put at designing homely, ungainly things, they couldn't surpass the array of hydrants we have got at the present day. Boston has got an art commission that passes on every drinking fountain and lamp-post and so forth, but something is put in for a hydrant that is about as ungainly as anybody can conceive of.

MR. MCINNES. The old saying is, "Handsome is as handsome does."

The President. From Mr. Brooks's remarks it would seem as though there were room for one more commission in Boston.

We should like to hear from Mr. Sullivan on this matter of fire hydrants.

Mr. William F. Sullivan.* Mr. President, I doubt whether I can add anything of interest to what has been already said. I have listened with attention and profit to the scientific paper read by the gentleman from Holyoke.

Up in Nashua, where I come from, some citizens believed they knew considerable about hydrants. I refer to a few worthy people who don't take into consideration the location and elevation of the hydrants, size of mains and connections, or the normal pressure for the particular locality; who believe that ordinarily a fire hydrant makes an unsightly hitching-post, and would rather see it placed in front of their neighbor's premises; yet under the stress and excitement of a fire, without reckoning into account the local conditions or the length of hose, they are ready to criticise if the nozzle fails to deliver enough water instantaneously to extinguish a conflagration.

We have made a practical test of hydrants; compiled tables showing location, make, diameter of barrel, direction of opening, whether they were 2-, 3-, or 4-way hydrants, with or without steamer outlet; also obtained the static pressure with the normal city draft, the indicated pressure with stream or streams flowing, the difference or loss due to the different flows. From this compilation we were able, with the aid of "Fire Stream Tables," to obtain the discharge per minute, and thus find the actual value of our hydrants as fire-fighting machines, and enabling us also to compare the efficiency of hydrants in different localities.

We also inspected the hydrants for durability, readiness for use, ease of operation, etc.; also whether they wasted freely, whether the packing needed renewing, whether the spindles were bent or defective, or any other defect impaired their usefulness. The result of such examination showed about 3 per cent. of the spindles needed replacing, about 8 per cent. needed repacking, 2 per cent. of the wastes needed attention, two hydrants needed replacing, several outlet caps were rusted or frozen on, so that

* Superintendent Pennichuck Water Company, Nashua, N. H.

it required considerable time and hammering to loosen and remove them.

In addition we also noted the horizontal distance in feet reached by a hose stream, the flow being through 50 feet of best 2½-inch rubber-lined hose and an underwriter's 1⅛-inch nozzle or play pipe; this gave us some idea also of the efficieney of our hydrants.

The number of hydrants found inefficient, or I might say, dummy hydrants, — or, in other words, that were not capable of delivering at least one good fire stream, — was very small; I should say less than 1 per cent.

This year we have remodeled the distribution system to some extent; that is, increased the pipe diameters in a number of streets. The hydrant data having been obtained before changes were made, we again tested the hydrants in the vicinity of the improvements, which enabled us to determine how much we improved the fire service in any section.

The form of tabulation used in our inspection is as follows:

PENNICHUCK WATER WORKS, NASHUA, N. H.

HYDRANTS.

Date.
Street.
Location.
Make.
Size standpipe.
Opens.
No. of nozzles.
  2-Way.
  3-Way.
  4-Way.
  Steamer.
Discharge 1⅛-inch nozzle attached to 50 feet 2½-inch hose (gage attached to hydrant).
  Pressures.
    Static.
    Stream flowing.
    Difference.
  Gallons per minute.
  Horizontal stream (feet). No allowance for wind.
Discharge through one open hydrant butt (gage attached to hydrant).
  Pressures.
    Static.

Stream flowing.
Difference.
Gallons per minute.
Discharge through open steamer butt (gage attached to hydrant).
Pressures.
Static.
Stream flowing.
Difference.
Gallons per minute.
Waste.
Packing.
Remarks.

As a record I believe that it is well to test and inspect hydrants periodically and find out their condition and value for the purposes for which they were installed.

We intend later to get the relative discharging capacities and the resultant loss of head of present-day commercial hydrants and their comparative costs.

The hydrant that is in most common use in our city is found suitable.

Our contract with the city of Nashua requires that all new hydrants shall be "Standard Six-Inch Hydrants." There seems to be a difference of opinion between water-works people, insurance underwriters, and fire departments as to what is a 6-inch hydrant. I should like to know whether a 6-inch hydrant means a 6-inch valve opening hydrant or a hydrant with a 6-inch barrel.

Mr. Stacy. Mr. President, it strikes me that this discussion has opened up another thought here. This Association has had various committees on different subjects to formulate standard rules for constructing different appliances for water works, and the importance of fire hydrants in water works seems to be so prominent that a committee might well be appointed on that subject, and if they put as much work into it as was put into the matter of standard specifications for cast-iron pipe by a committee, I think we would meet with some results.

The question has been asked, What is a 6-inch hydrant? We buy them. You may get a 6-inch post, you may get a 4-inch gate; you talk with somebody about it, and they say, "That 4-inch or 5-inch gate will give you as much water as a 6-inch post."

I hardly believe that myself; but a test might prove them right. I believe that an 8-inch pipe and an 8-inch gate and an 8-inch post will give me more water than a 5-inch gate and a 6-inch post and an 8-inch supply. I believe that where you want lots of water an 8-inch pipe is not any too much, and I want the gate pretty nearly the same size, too. However, that might be modified, perhaps, on investigation.

It seems to me that this is a function that this Association should take up; and I think we might evolve from that a Standard Hydrant of the New England Water Works Association that would be recognized as something better than what is put on the market to-day.

Now, if we have a standard hydrant,— as an underwriters' fire pump is standard,— then you would all be figuring on the same basis and the same construction, and we would know better where we stand when we come to buy hydrants, as to opening, quality of workmanship and capacity, gates, and everything else.

MR. JOHN H. FLYNN.* I would like to ask if a hydrant with a 6-inch valve opened with pressure with a 7-inch barrel would be a 6-inch hydrant?

THE PRESIDENT. My impression is that that is something that remains to be settled. [Laughter.] It depends, I think, on the manufacturer. It sometimes depends on the man who is ordering the hydrant. I think that is something that would be covered by such a committee as Mr. Stacy suggests.

It seems to me that Mr. Stacy's ideas on that subject are most excellent.

MR. STACY. I think a committee of five is large enough, and I should say it ought to be about that size. I haven't given that a great deal of thought, but, to bring it up before you, gentlemen, I move that a committee of five be appointed by the president to take up the subject of hydrant construction.

MR. FLYNN. Mr. President, I second that motion.

THE PRESIDENT. It is moved and seconded that the president appoint a committee of five to consider and report on hydrant construction.

[The motion was put by the president, and declared to be a vote.]

* Assistant Superintendent, Boston Water Works.

MR. THOMAS. Mr. President, would it be a good idea to hear from some of the hydrant manufacturers? We have had one side of the case. I think Mr. Bates is here from the Rensselaer Manufacturing Company, Mr. Gould from the Ludlow Valve Manufacturing Company, and Mr. Hughes of the Chapman Valve Manufacturing Company. Wouldn't it be a good idea to hear from them on the hydrant matter?

THE PRESIDENT. The Association will be pleased to hear from any of those gentlemen. I think Mr. Bates comes nearest to heading the alphabet.

MR. F. S. BATES. Mr. President and gentlemen, the reading of this paper on fire hydrants brought up a most interesting subject, and the remarks made here to-day on the construction of fire hydrants are very interesting, not only to the active members of the New England Water Works Association, but also to the associate members who are actively engaged in the manufacture and sale of these fire hydrants to the various water departments.

I have found in my twenty-three years of experience, both from the manufacturing and the sales point of view, that all material consisting of either valves or fire hydrants should be purchased direct by the various water departments and not through contractors who are building the work, as they have a tendency to force the material or supply representatives to an extremely low figure before they will place their orders, and as a result the cities will suffer in the end by the cheapest and poorest material being introduced. The contractor looks at it from his point of view that the water board will stand behind him and will adopt whatever material he sees fit to purchase. As the specifications do not specify the design or the character of the hydrant, therefore the contractor accepts the lowest proposal possible to obtain on valves and hydrants and inserts these into his proposal, the result of which, in submitting his bid to the city, and using the lowest possible prices to obtain on material, would naturally make his total bid the cheapest but not the most beneficial to the city.

Therefore, if the water board does not take into careful consideration the durability of the material in the contractor's proposal, but simply awards the contract as a whole on account of its being the lowest proposal presented, and allows the contractor

to purchase his own valves and hydrants, the various city water departments are handicapped under such conditions and are, in a great many cases, forced to accept material which is detrimental to their department, while if they were purchasing direct they would go farther and investigate carefully the construction and details as well as the design of the valves and hydrants.

As Mr. Stacy said, there should be more and more careful work done in the machine shop; but what can a manufacturer do when he is forced to the lowest price limit and has the above questions to consider? I have also found from personal observation that frequently the workmanship and durability of either valves or hydrants has not been taken into consideration at all, but it is simply a question of price, which is a mistake. It is always for the best interest of water departments, and the communities which they represent, that they should recommend for adoption in their systems valves and hydrants that stand the highest in workmanship and durability. I also find that the majority of superintendents and engineers of private corporations give much more consideration to the details of construction of their various appliances before they are adopted than officials of our various cities usually do to the merits or demerits of the same. The corporation's point of view is, that they want an appliance that will stand, so that the repairs and cost of maintenance will be a nominal sum at the end of the fiscal year, but in many cities this important factor is not considered at all. It is a question of first cost only. "How much can they buy this or that article for?" and in nine out of ten cases the price of a good article seems too high, and the lowest price, and consequently the cheapest and poorest valve and hydrant, are taken, although, I assure you, that the prices submitted to-day by the reputable concerns making valves and hydrants are exceptionally low ones, considering the price of raw material and labor.

In regard to screwing the 2½-inch nozzle into the standpipe: it is an excellent idea and should be adopted by all water works. In well-regulated shops there is no difference in the cost of construction between a nozzle that is leaded in and one that is screwed in, but the one that is screwed in will render the best service and be more easily replaced in case of accident. Consider the con-

struction of the nozzles in the fire hydrants in use at Coney Island, where the nozzles are leaded in and were melted out by the heat of the fire. I had the honor of receiving this order, and before proceeding with the construction of hydrants we recommended to the department that they should be screwed in, but it was considered it might be a detriment to the hydrant to have them screwed in. I showed them the method of screwing nozzles into hydrants, and that by putting a thread in the standpipe reverse to that on the hose end of the nozzles it would keep such nozzle in place; and by putting a set screw on the outside of the nozzle through the cast-iron part it would also prevent this nozzle from unscrewing out of the hydrant during the taking off or putting on of the hose connection. Unfortunately, we find also that in a large number of the cities and towns of New England the hydrants are furnished with the nozzles leaded in, but if superintendents and engineers, on issuing their orders, would specify or request that their hydrant nozzles be screwed in we would only be too glad to furnish the same.

In relation to the standardization of hose threads and operating nut, we have recommended and furnished the same to new water works plants and have also recommended same to those who seemed desirous of adopting some other city standard. A large number of cities are recommending this change, so that in due course of time a large percentage of our water departments will have this new style of thread and operating nut, for which, of course, this water works association deserves some of the credit.

I do not know as I could add anything more to this important subject, but the points that I have demonstrated to you I consider are valuable ones and should be taken into careful consideration by the various superintendents here. I speak only as one of the associate members, as we are all here for the purpose of trying to bring before the active members the latest improved water-works devices and those that are best designed and constructed and suited for their water-works systems.

It is a great and difficult study for us to please all, but we are always willing to take advice and suggestions that are given. After we have ferreted out and proved suggestions given us by

you gentlemen, and find they will be of benefit to our hydrants and valves, we are willing to accept and manufacture the same.

I thank you, gentlemen, for your attention, and also for the invitation extended to me to make a few remarks on this subject.

THE PRESIDENT. We would like to hear from Mr. Hughes, of the Chapman Valve Manufacturing Company.

MR. HUGHES. I don't know that I can add anything to what Mr. Bates has said, Mr. President. If this matter was taken up and thoroughly thrashed out, I think you would get a better distribution of metal in a great many cases, a different kind of metal, more suitable for the purposes than is used sometimes.

As regards Mr. Bates's remarks on screwed nozzles, I think that can be thrashed out in debate; I don't quite agree with him; I can see some trouble in water departments through having screwed nozzles.

THE PRESIDENT. We should like to hear from Mr. Gould. I don't get my eye on him, but I think he is here somewhere.

[Mr. Gould was not present at this time.]

THE PRESIDENT. My impression is that a committee of this Association — possibly two years ago — recommended that the hydrant have cast upon its top an arrow showing the direction in which it should be opened. As we have some hydrant men here I should like to inquire if that recommendation has ever been carried out by the hydrant builders.

MR. HUGHES. I saw you looking this way, Mr. President, and I will say that the hydrants that I am familiar with have the arrow.

MR. FLYNN. I don't know that it would make much difference whether there was an arrow or not. [Laughter.]

MR. F. L. FULLER.* Mr. President, there is one matter I think might be brought up in connection with this paper, and that is the care of hydrants. I think in many towns and cities hydrants are very much neglected. I had occasion during the past summer to examine about one hundred and twenty hydrants in a certain town, and I was surprised to find in what poor condition they were. They were of various manufactures and apparently very little attention had been given to them for a long time. In many of them the

* Civil Engineer, Boston, Mass.

packing had largely disappeared, and almost all of them had been screwed down to such a degree that they could not be started with an ordinary wrench. I found that those who had previously used them (for the most part men employed in flushing sewers) had opened and closed them with a very long wrench. Wrenches more than three feet long were sometimes used.

It seems to me that a hydrant, of all things, is an instrument or appliance which ought to be kept in the very best order. Yet I venture to say that in a great many towns the hydrants are, to a considerable extent, in poor working condition. They open hard; there are no washers, perhaps, in the nozzle caps, so that if only one line of hose is attached there is a large stream of water flowing from the other nozzle. I found this to be the case especially where there were steamer nozzles; there was generally no washer, no packing in these nozzle caps, and a large stream of water escaped from the hydrant because the cap did not make a tight joint with the hydrant.

A hydrant ought to open and close easily; it ought to be closed only sufficiently to open the drip and properly close the inlet valve, and it ought to be so oiled or greased that it will turn easily. A great many of the hydrants referred to squeaked while being opened or shut, which seemed to indicate that nothing had been done in the way of lubrication for a long time. Oftentimes a stream of water came out between the hydrant and the hydrant head. To say nothing of the water thus wasted, which should be used for extinguishing the fire, it is, to say the least, unpleasant for firemen to be obliged to stand by and manipulate a hydrant, from which the water is spurting in all directions. In cold, freezing weather this duty becomes doubly disagreeable. It is inexcusable that hydrants should be found in such a condition. I believe the water department of a town or city should have entire charge of all hydrants at all times, except in case of fire or during fire drills or practice, and the water department should be held responsible for their condition.

Watering carts should be filled from standpipes properly located, and not from hydrants.

In flushing sewers with hose from a hydrant, a large and generally unknown quantity of water is used. The sudden draft of

water is liable, in some systems, to cause consumers annoyance by furnishing them with roily water, although it may be argued that in such a case the blowing off of the hydrants is an advantage, as it tends to keep the pipes clean. When the supply is of good quality, it is seldom necessary to blow off the hydrants, except, perhaps, at dead ends, where the consumption may be small.

A method of flushing sewers which obviates the necessity of using hydrants, and is generally satisfactory, is to provide the manholes at summits with a simple iron flushing gate or plug by which the outlet can be temporarily closed. Water is admitted to the manhole by means of a faucet or valve in the manhole attached to a service pipe from the nearest main. When the water has reached a suitable height in the manhole, the outlet is suddenly opened by raising the gate or withdrawing the plug by means of a chain attached thereto. This allows the outflow of a considerable quantity of water, causing a thorough flush. This water can, of course, be metered, if desired, as it enters the manhole.

The proper care of hydrants is certainly an important matter.

MR. JOHN C. CHASE.* Mr. President, I would like to follow up the line of thought suggested by Mr. Fuller. The fire hydrant is a fixture that has a specific function in a water works plant. It is ordinarily used infrequently, but when its service is wanted at fires there is nothing that will take its place. Now I maintain that it should be kept religiously for the purpose for which it was designed; that is, as a part of the fire-fighting apparatus, and its non-use for every other purpose should be firmly insisted upon except under the supervision of the water department. I have always made that a point in the management of the works with which I have been connected, and with giving them a regular and proper amount of attention to see that they are in good working order, and watching out to see that they are not maliciously interfered with, they have always been ready to respond when called upon.

Another thought that has been suggested by Mr. Bates is in relation to the cheapening of hydrant and valve construction. I

* Civil Engineer, Derry, N. H.

do not think the manufacturers are so much to blame for any inferior quality of their product as the purchasers, who are calling for the lowest possible price for the article they want. Now a little illustration of contractor's methods, or, perhaps I should say, the method of one that came under my own observation: Some thirty-five years ago a New Hampshire city built a system of water works, and the whole pipe system with hydrants and valves was let, in one contract, to a prominent New England contractor. It was specified that he should furnish certain well-known hydrants and valves made by a reliable manufacturing company, which were to be first-class in every particular. When the works were about half completed water was furnished for a limited use and the hydrants were put into service. It was noticed that there was a slack motion in the valve rod of some of them and when a hydrant was being used on the lower level, where the pressure was some 85 pounds to the square inch, the valve seated itself suddenly when it was nearly closed and the resulting water hammer caused the hydrant and supply pipe to part company, with a disastrous effect upon the street in the immediate vicinity.

The maker of the hydrants was notified to appear and make good the defects. The mechanic who was sent up incidentally remarked that we " could not expect anything better from second-class work." " Second-class work! why, we called for the best." " Well, I do not know what you called for, but this is not our best work; you do not find our name upon it, do you? " And I had to admit that he was right. Work had been sent out that the makers did not care to have their name upon, but they made the deficiencies good, however. When the works were tested upon completion, some two years later, with a large number of fire streams playing, one of the hydrants suddenly stopped work and the water began to boil up on the outside. It turned out that in opening it an excessive strain had been put on the valve rod, which struck the post at the bottom and broke a hole through the shell. Later inspection showed that several unused hydrants were lacking in proper thickness at the base. Here was a case where a concern with a reputation for first-class work had, in order to meet competition and the demands of the contractor,

sent out what was not up to the required standard, with a consequent loss of money and reputation.

MR. THOMAS. Mr. President, isn't it a fact that there are not hydrants enough used in cities, and that they are not distributed numerously enough around, especially in the central parts of the city?

I think I can safely say, without even speaking in the interests of the hydrant manufacturers, that there are too few hydrants used; they ought to be nearer together; then if one of them is out of order, you have another close by that you can use. Where the hydrants are placed 1 000 feet apart there ought to be three instead of one; then if one was out of order, you would have two more to fall back upon. I don't believe in a few big hydrants so much as I do in a number of smaller hydrants. Have them closer together; do away with the friction of long lines of hose.

I believe that the hydrant manufacturers, if they are given time and sufficient notice, will furnish all the hydrants required, and furnish them just as the water-works people want them. The trouble is not with the hydrant manufacturers altogether. All the superintendents have got to do is to take their JOURNAL and look at the advertising pages; they will find there the names of hydrant manufacturers who make hydrants first class in workmanship and of high-grade material.

I should urge upon all the superintendents not to be sparing in putting in hydrants. But don't put them in front of every man's house that you have a grievance against. [Laughter.]

MR. FLYNN. I should like to say to Mr. Thomas that I don't see any use of putting in too many hydrants. If a hydrant gets out of order I don't know what good it is going to do to have one next door to it, because the engine can't get away from it, but has got to stay right there until the water works people come along and unhitch it. [Laughter.]

MR. THOMAS. There isn't any fireman that I ever knew of that would stand in front of a stream.

MR. HUGH MCLEAN.* Something has been said about the care of hydrants. I would like to cite you a case where I know hydrants are taken care of, and that is the city of Holyoke. I believe a

* Chairman Water Board, Holyoke, Mass.

city of 20 000, 30 000, 50 000, or 100 000 population or over ought to have a hydrant man in its water department, a man who responds to all fire alarms, and after the fire is over sees that the hydrants are closed down tight as they ought to be, and goes round and examines them and sees that they are all right and properly drained off; a man whose duty it would be to go around to the hydrants twice a year and flush them off, and see that they are thoroughly in order.

We have such a man in our city, and that is his duty — taking care of hydrants. We have a fire alarm gong in his bedroom and he responds to all fire alarms and takes his hydrant kit along with him; if there is anything wrong about the hydrant he telephones down to the shop immediately and a couple of men come right along. No hydrant is opened without his permission; that is, unless for fire purposes. Through the day, if they are needed for sewer flushing or any other purposes, they must be opened by him and closed by him; so that, if anything is wrong about the hydrant, should it freeze up or be out of order, then the department is responsible through him.

I believe that there is no better system of taking care of hydrants than in having a man in every department whose duty it will be to respond to fire alarms and take care of the hydrants when the fire is over.

Mr. Stacy. Mr. President, from the remarks of brother Thomas I know how he feels in his position, that we are criticising the hydrant makers. I know he feels pretty tender on that point, and well he should, because I think that his success as our advertising agent has depended a good deal on his tender heart. [Laughter.] Really, without any joking, I don't take this to be a criticism of the manufacturers of hydrants, because I think they are giving us just what we are asking for, and as good a thing as they can for the price we are willing to pay.

And I believe another thing: After you get a good hydrant or a good watch, in order to keep it good you have got to take care of it. Up in our little city of 15 000 inhabitants nobody uses a hydrant without permission, except in case of fire. When the highway department or the sewer department want to use a hydrant I furnish a man to operate it. I have held to that.

Sometimes it has been uphill work and I have had to make myself disliked in some quarters, but I have carried that point because I believed it was right. I would say that the relations between the highway and water department, with one or two exceptions, have always been pleasant.

We have a man who is responsible for the care of hydrants and responds to fires. Unfortunately, I am the fellow. [Laughter.] I have a gong in my house, and my wife wishes it was in somebody's else house. [Laughter.] Some time we may be large enough to have a man whose only business will be to take care of the hydrants.

The way I do with the street department is this: In the spring I give the man who runs the steam roller a numbered hydrant wrench; and he reports what hydrants he uses and he returns the wrench in the fall.

If any department desires the use of a hydrant, I try to accommodate them in every possible way, but I insist on keeping the hydrants in my control as long as they hold me responsible for them.

We shall have better hydrants when we demand them and when we are willing to pay for them, and when we get them they will be good hydrants just as long as we are willing to take care of them.

The President. Mr. Brooks, don't you admire Mr. Stacy's success in keeping other people away from the hydrant?

Mr. Brooks. I wish he would come down our way.

Mr. Stacy. Perhaps under other conditions that would be impossible. It isn't one man's smartness, it is the sentiment that happens to grow up and the class of men that surround you and have the power to back you up. I know places where it is impossible for the superintendent to do that, because there are other influences that come in and prevent him.

As far as the number of hydrants is concerned, I think that's another good point. I believe in plenty of hydrants, and I have tried to practice what I preach in that matter. In all of our factory places I can put on 12 to 16 streams, and the longest line of hose will not be over 300 feet. Working at a fire the lines would be somewhat longer.

So I say that the hydrant makers are all right, brother Thomas, and they make good hydrants, and will make better ones if we demand them.

MR. GEORGE CASSELL.* This paper that has been read here this afternoon deals, as I understand it, largely with the friction loss in the different fire hydrants manufactured. Now it seems to me that that is a matter that is purely up to the manufacturers of hydrants, and with this table showing the results that it does, it seems to me that it ought to be an incentive to the representatives of the different manufacturers who are assembled here this afternoon to get a hustle on [laughter], because there is no doubt in my mind but what in the future I will make an attempt to secure the hydrant with the least friction loss.

In relation to the condition of fire hydrants, I don't think the trouble is confined wholly to the hydrant. I believe, as has been stated here this afternoon, that it is due to the manipulation of the fire hydrants by people who do not understand the mechanism of them. In my city that is the only trouble I have, and I am sorry to say that I am unable to stop it, simply because, as my friend Stacy here has said, of the interference of others who are a little higher up.

I had a case of that kind where I issued an order to the superintendent of streets and city engineer that he should not manipulate any fire hydrants for any purpose without notifying the department, and that the department would furnish men to manipulate them for him. Well, he didn't seem to like that very well, so he went up to the mayor (not the present mayor, but a mayor three or four terms back; yes, six or seven, because the present mayor as is, has been mayor for the last five years), and the mayor said to him, "Don't you pay any attention to that; you use the fire hydrants all you want to." Well, that was all right enough, and didn't bother me for a cent. I met the mayor on the street a few evenings afterwards, and it happened to be just before election for the executive of the city. He said to me, "What is all this row about the fire hydrants?" I said, "I didn't know there was any row about the fire hydrants, I didn't hear any." He said, "The city engineer has told me you

* Superintendent of Water Works, Chelsea, Mass.

notified him not to use them any more." I said, "Yes, I did." He said, "I told him to use them all he wants to." I said, "Very well, the responsibility for their condition is up to you now, not on the water department." He said, "What do you mean by that?" I said, "Come round the corner and I will show you." It happened to be in the winter time and they had been laying vitrified brick and had been using the water from hydrants for making the concrete base, and I had just come from an examination of two hydrants which were frozen to the nozzle. I showed them to him and said, "That is what I mean." He said, "You find out who did that." I said, "No, sir; you find out." [Laughter.] I said, "I am going to have them put in condition, but if there is any finding out to do you will do it and I won't." He said I was trying to make all the trouble I could just before election.

Now, gentlemen, the fire hydrants (with the exception of the friction loss that has been talked about here), so far as I have been able to learn in my experience of a great many years, are all right if let alone or manipulated by men who understand the mechanism of them. And until we can get those in authority to back us up in not allowing the use of those hydrants by people for street watering purposes, or any other purpose, then just so long will we have that trouble.

Now, the mayor that I have just been telling you about was in the insurance business, and still he told that man to use all the hydrants just as much as he wanted to! So you can see that the fault is not with the hydrant; it is not with the superintendent or whatever official is in charge of them, but it is with those who interfere with the business of the superintendent. And there is no trouble that comes so quickly or is so great as the trouble that comes from somebody minding somebody's else business.

We are troubled in our city with the drips, as Mr. Stacy mentioned, but we take all the precaution within our power to prevent our hydrants from being frozen in the winter time, and it requires some supervision. There are numerous cases where hydrants will freeze under certain conditions. For instance, our hydrants are set at 5-foot bottom. Now there are different kinds of soil, and we find that in severe winters like the past the frost will go down

in gravelly soil and we have got to examine and test those hydrants almost every twenty-four hours, especially where the railroad tracks cross above the pipes leading to them.

In regard to the hydrants with the drips that are liable to fill up with surface water, we have that to contend with. And in such cases we plug the drip port and keep the hydrants pumped out, and make an examination in thoroughly cold weather almost every day, sometimes twice, of all hydrants. But it pays to do it. And we have never been caught yet, to my knowledge, with a frozen hydrant when it was needed. Perhaps it was because it wasn't needed when it was frozen. [Laughter.]

We don't want to blame the hydrants, because nine times out of ten the hydrants are not to blame, and I believe that (with the possible exception of what has been brought forward in this paper on friction loss) there is almost no fault to be found, although there is always room for improvement, and the manufacturer who gets on the ground first is going to be the winner.

STREAM FLOW DATA FROM A WATER-POWER STANDPOINT.

BY CHARLES E. CHANDLER, CIVIL ENGINEER, NORWICH, CONN.

[*Read November 13, 1907.*]

Long-term data regarding stream flow are not abundant. Records of the Croton flow have been kept continuously longer than on any other stream, so far as the writer knows. I am not aware that the Croton thirty-eight-year record is anywhere in print in one table, as shown in Table No. 1. There is a gap in the data in the water supply and irrigation papers, which it was found somewhat difficult to fill.

Stream-flow data arranged by months chronologically do not average fairly, and the next table has the same data with the months arranged in order of magnitude. This table (No. 2) is much more useful for water-power purposes than the first one.

A still further improvement may be made, so far as the lower flows are concerned, by arranging all the months in the whole term in order of magnitude as in Table No. 3, instead of arranging the months in each year in order of magnitude.

Table No. 4 compares the results obtained by the three methods shown in preceding tables, and shows how much nearer to the truth is the last method.

The arrangement of Table No. 3 is absolutely correct in its theory. Whenever the flow of a stream is greater than can be used by the water wheels installed, a part of the flow is unavailable. Water-wheel developments, as a rule, leave much water to run over the dams unused. Arranging all the months of the whole term in order of magnitude, instead of each year separately, eliminates all that part of all flows that must run over the dam instead of through the wheels at any given development.

The information to be obtained, working on this principle, is given in greater detail, and in days as well as months, in Table No. 5. Column A gives all the monthly flows that occurred during the thirty-eight years in order of magnitude, and in

column B the number of months in which each flow occurred during the whole period. Column C masses these months and hence gives the number of months in which a given flow, and flows less than the given flow, occurred. Multiplying the massed months by 0.8 gives in column F the annual average massed days. (30.4 days in the average month; record covers 38 years; $30.4 \div 38 = 0.8$.)

By multiplying the given flows by the number of months in which they occurred (column D) and massing the products (column E) and dividing by the massed months, we have in column G the average flow of the massed months. Column H gives the average available flow at all developments in column A.

The Croton flow was used for this illustration, not only because of the length of the period of observation, but because its watershed is larger than that of other water supplies, regarding the flows of which long term records exist, making the data more useful for power purposes.

Of course, these or any other data that are computed monthly do not show the real extreme minimum flow, and at moderate developments considerable unavailable stream flow is included as available.

The daily records of the Connecticut at Holyoke furnish very valuable stream flow data for power purposes.

The idea of arranging in order of magnitude the different flows of the whole term covered by the data, instead of treating each year separately, occurred to the writer several years ago when reporting on several large waters powers for a power company.

The Holyoke data kindly given him by Mr. A. F. Sickman were in form of second feet for the whole of the drainage area for each day of each year in order of magnitude. These have been reduced to second feet per square mile and arranged as shown in Table No. 6.

TABLE No. 1.

CROTON RIVER. DRAINAGE AREA, 338.8 SQUARE MILES. MONTHLY DATA. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE ARRANGED CHRONOLOGICALLY.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.	Average.
1868	1.52	.68	3.39	3.04	4.64	2.64	.85	1.59	.44	2.29	2.75	1.21	25.04	2.45
1869	1.74	1.69	4.32	2.71	2.21	1.05	.46	.26	.16	2.07	1.66	2.49	20.82	1.74
1870	3.07	3.70	2.74	3.59	1.38	.64	.39	.39	.28	.33	.49	.46	17.46	1.44
1871	.45	1.90	2.71	1.57	1.56	1.12	.53	.65	.48	1.54	2.98	1.74	17.23	1.43
1872	1.58	.99	1.33	2.47	.96	.94	.46	1.26	.95	.83	2.12	1.08	14.97	1.24
1873	3.33	1.42	3.14	5.79	1.65	.42	.37	.55	.41	1.09	1.34	2.32	21.83	1.84
1874	8.19	2.37	2.31	2.89	2.45	.70	1.08	.67	.45	.59	.54	.70	22.94	1.83
1875	.46	3.55	2.49	4.51	1.39	.44	.43	4.22	.67	.63	1.74	1.36	21.89	1.81
1876	1.10	3.07	5.52	5.03	1.53	.53	.41	.38	.30	.29	.55	.36	19.07	1.58
1877	.61	1.25	5.37	2.34	.67	.47	.38	.37	.27	.79	3.45	1.49	17.46	1.46
1878	2.24	3.31	3.00	1.31	1.17	1.15	.55	.49	1.87	.69	1.64	6.06	23.48	1.95
1879	1.07	2.36	3.31	4.08	1.45	.69	.55	1.08	.87	.48	.62	1.46	18.02	1.49
1880	2.09	2.41	2.26	1.63	.67	.41	.41	.38	.39	.38	.44	.41	11.88	.98
1881	.56	3.91	4.69	1.47	1.04	1.34	.43	.41	.41	.41	.36	1.36	16.39	1.35
1882	1.81	3.79	4.03	1.11	1.78	1.33	.52	.41	2.65	1.72	.74	.98	20.87	1.73
1883	.86	2.98	2.25	2.17	1.03	.53	.41	.41	.39	.50	.53	.47	12.53	1.03
1884	1.54	4.77	3.96	2.40	1.46	.52	.63	.92	.57	.42	.78	3.04	21.01	1.72
1885	3.38	2.18	1.57	2.09	1.21	.46	.39	.44	.35	.42	1.67	1.62	15.78	1.31
1886	2.75	4.22	1.94	3.81	1.65	.63	.46	.43	.39	.39	.69	.93	18.29	1.50
1887	2.24	4.42	2.94	2.69	1.01	.94	2.09	2.81	.72	.81	.77	1.92	23.36	1.93
1888	3.24	4.06	3.79	4.13	2.12	1.11	.43	.85	2.67	2.00	2.54	4.25	31.19	2.59
1889	3.55	2.04	1.62	2.08	1.34	1.45	1.23	3.29	1.85	1.49	4.41	3.70	28.05	2.32
1890	1.78	2.82	3.86	2.68	2.09	1.35	.66	.48	1.71	2.68	1.69	1.33	23.13	1.91

1891	5.62	5.19	3.45	2.01	.74	.64	.65	.67	.66	.64	.56	.98	21.81	1.80
1892	2.97	1.23	1.49	.97	1.15	.98	.73	.71	.78	.68	1.24	1.30	14.23	1.19
1893	1.49	2.55	5.09	2.83	4.79	.84	.74	.86	.75	.98	1.25	2.60	24.77	2.06
1894	1.31	1.83	4.03	1.93	1.47	1.25	.76	.74	.77	.72	1.95	1.77	18.53	1.54
1895	2.35	.91	2.68	3.15	1.04	.75	.75	.78	.82	.75	.72	.75	15.45	1.29
1896	1.03	2.07	4.62	2.34	.47	.92	.85	.92	.88	.89	1.29	.91	17.19	1.47
1897	1.10	1.90	2.44	2.01	2.26	1.19	2.13	2.44	1.01	.88	.91	1.79	20.06	1.68
1898	2.98	4.34	2.62	1.76	3.89	1.55	.95	1.77	1.03	1.15	1.67	2.67	26.38	2.19
1899	3.17	2.57	6.06	3.30	.99	1.03	1.01	1.05	1.02	1.04	1.04	1.03	23.31	1.94
1900	1.53	6.26	4.77	1.73	2.19	.63	.39	.10	.27	.48	1.18	1.67	21.20	1.74
1901	1.06	.46	4.47	6.78	3.70	1.44	1.23	3.75	1.93	2.32	1.11	4.08	32.33	2.71
1902	3.28	2.82	8.55	2.88	1.56	.74	.64	.50	.62	2.10	1.27	4.79	29.75	2.49
1903	3.15	3.56	5.24	3.02	.54	2.95	1.36	1.32	1.62	4.35	1.53	2.36	31.00	2.58
1904	2.00	2.62	4.73	2.85	1.42	1.04	.74	1.06	2.28	1.38	1.23	.95	22.30	1.86
1905	3.80	1.13	3.76	3.11	.80	1.04	.33	.45	1.17	.64	.54	1.03	17.80	1.50
Total...	86.00	103.33	136.54	106.26	63.47	37.85	27.38	39.86	34.86	41.84	51.99	69.42	798.80	
Average ..	2.26	2.72	3.59	2.80	1.67	1.00	.72	1.05	.92	1.10	1.37	1.83	1.75	

TABLE No. 2.

CROTON RIVER. DRAINAGE AREA, 338.8 SQUARE MILES. MONTHLY DATA. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE ARRANGED IN ORDER OF MAGNITUDE IN EACH YEAR.

	1	2	3	4	5	6	7	8	9	10	11	12	Total.	Av.
1868	.44	.68	.85	1.21	1.52	1.59	2.29	2.64	2.75	3.04	3.39	4.64	25.04	2.45
1869	.16	.26	.46	1.05	1.66	1.69	1.74	2.07	2.21	2.49	2.71	4.32	20.82	1.74
1870	.28	.33	.39	.39	.46	.49	.64	1.38	2.74	3.07	3.59	3.70	17.46	1.44
1871	.45	.48	.53	.65	1.12	1.54	1.56	1.57	1.74	1.90	2.71	2.98	17.23	1.43
1872	.46	.83	.94	.95	.96	.99	1.08	1.26	1.33	1.58	2.12	2.47	14.97	1.24
1873	.37	.41	.42	.55	1.09	1.34	1.42	1.65	2.32	3.14	3.33	5.79	21.83	1.84
1874	.45	.54	.59	.67	.70	.70	1.08	2.31	2.37	2.45	2.89	8.19	22.94	1.83
1875	.43	.44	.46	.63	.67	1.36	1.39	1.74	2.49	3.55	4.22	4.51	21.89	1.81
1876	.29	.30	.36	.38	.41	.53	.55	1.10	1.53	3.07	5.03	5 52	19.07	1.58
1877	.27	.37	.38	.47	.61	.67	.79	1.25	1.49	2.34	3.45	5.37	17.46	1.46
1878	.49	.55	.69	1.15	1.17	1.31	1.64	1.87	2.24	3.00	3.31	6.06	23.48	1.95
1879	.48	.55	.62	.69	.87	1.07	1.08	1.45	1.46	2.36	3.31	4.08	18.02	1.49
1880	.38	.38	.39	.41	.41	.41	.44	.67	1.63	2.09	2.26	2.41	11.88	.98
1881	.36	.41	.41	.41	.43	.56	1.04	1.34	1.36	1.47	3.91	4.69	16.39	1.35
1882	.41	.52	.74	.98	1.11	1.33	1.72	1.78	1.81	2.65	3.79	4.03	20.87	1.73
1883	.39	.41	.41	.47	.50	.53	.53	.86	1.03	2.17	2.25	2.98	12.53	1.03
1884	.42	.52	.57	.63	.78	.92	1.46	1.54	2.40	3.04	3.96	4.77	21.01	1.72
1885	.35	.39	.42	.44	.46	1.21	1.57	1.62	1.67	2.09	2.18	3.38	15.78	1.31
1886	.39	.39	.43	.46	.63	.69	.93	1.65	1.94	2.75	3.81	4.22	18.29	1.50
1887	.72	.77	.81	.94	1.01	1.92	2.09	2.24	2.69	2.81	2.94	4.42	23.36	1.93
1888	.43	.85	1.11	2.00	2.12	2.54	2.67	3.24	3.79	4.06	4.13	4.25	31.19	2.59
1889	1.23	1.34	1.45	1.49	1.62	1.85	2.04	2.08	3.29	3.55	3.70	4.41	28.05	2.32
1890	.48	.66	1.33	1.35	1.69	1.71	1.78	2.09	2.68	2.68	2.82	3.86	23.13	1.91

1891	.56	.64	.64	.65	.66	.67	.74	.98	2.01	3.45	5.19	5.62	21.81	1.80
1892	.68	.71	.73	.78	.97	.98	1.15	1.23	1.24	1.30	1.49	2.97	14.23	1.19
1893	.74	.75	.84	.86	.98	1.25	1.49	2.55	2.60	2.83	4.79	5.09	24.77	2.06
1894	.72	.74	.76	.77	1.25	1.31	1.47	1.77	1.83	1.93	1.95	4.03	18.53	1.54
1895	.72	.75	.75	.75	.75	.78	.82	.91	1.04	2.35	2.68	3.15	15.45	1.29
1896	.47	.85	.88	.89	.91	.92	.92	1.03	1.29	2.07	2.34	4.62	17.19	1.47
1897	.88	.91	1.01	1.10	1.19	1.79	1.90	2.01	2.13	2.26	2.44	2.44	20.06	1.68
1898	.95	1.03	1.15	1.55	1.67	1.76	1.77	2.62	2.67	2.98	3.89	4.34	26.38	2.19
1899	.99	1.01	1.02	1.03	1.03	1.04	1.04	1.05	2.57	3.17	3.30	6.06	23.31	1.94
1900	.10	.27	.39	.48	.63	1.18	1.53	1.67	1.73	2.19	4.77	6.26	21.20	1.74
1901	.46	1.06	1.11	1.23	1.44	1.93	2.32	3.70	3.75	4.08	4.47	6.78	32.33	2.71
1902	.50	.62	.64	.74	1.27	1.56	2.10	2.82	2.88	3.28	4.79	8.55	29.75	2.49
1903	.54	1.32	1.36	1.53	1.62	2.36	2.95	3.02	3.15	3.56	4.35	5.24	31.00	2.58
1904	.74	.95	1.04	1.06	1.23	1.38	1.42	2.00	2.28	2.62	2.85	4.73	22.30	1.86
1905	.33	.45	.54	.64	.80	1.03	1.04	1.13	1.17	3.11	3.76	3.80	17.80	1.50
Total.....	19.51	24.44	27.62	32.43	38.40	46.89	54.19	67.89	81.30	102.53	128.87	174.73	798.80	
Average ..	.51	.64	.73	.85	1.01	1.23	1.43	1.79	2.14	2.70	3.39	4.60	1.75	

TABLE No. 3.

CROTON RIVER. 1868 TO 1905 INCLUSIVE.
DRAINAGE AREA 338.8 SQUARE MILES. MONTHLY DATA.

Flow in cubic feet per second per square mile arranged in order of magnitude for whole term instead of each year separately.

1	2	3	4	5	6	7	8	9	10	11	12
.10	.42	.54	.70	.91	1.06	1.33	1.59	2.00	2.44	3.02	4.03
.16	.42	.54	.71	.91	1.06	1.33	1.62	2.01	2.45	3.04	4.03
.26	.42	.54	.72	.91	1.07	1.33	1.62	2.01	2.47	3.04	4.06
.27	.43	.55	.72	.92	1.08	1.34	1.62	2.04	2.49	3.07	4.08
.27	.43	.55	.72	.92	1.08	1.34	1.63	2.07	2.49	3.07	4.08
.28	.43	.55	.73	.92	1.08	1.34	1.64	2.07	2.54	3.11	4.13
.29	.43	.55	.74	.93	1.09	1.35	1.65	2.08	2.55	3.14	4.22
.30	.44	.56	.74	.94	1.10	1.36	1.65	2.09	2.57	3.15	4.22
.33	.44	.56	.74	.94	1.10	1.36	1.66	2.09	2.60	3.15	4.25
.33	.44	.57	.74	.95	1.11	1.36	1.67	2.09	2.62	3.17	4.32
.35	.44	.59	.74	.95	1.11	1.38	1.67	2.09	2.62	3.24	4.34
.36	.45	.61	.74	.95	1.11	1.38	1.67	2.10	2.64	3.28	4.35
.36	.45	.62	.75	.96	1.12	1.39	1.69	2.12	2.65	3.29	4.41
.37	.45	.62	.75	.97	1.13	1.42	1.69	2.12	2.67	3.30	4.42
.37	.46	.63	.75	.98	1.15	1.42	1.71	2.13	2.67	3.31	4.47
.38	.46	.63	.75	.98	1.15	1.44	1.72	2.17	2.68	3.31	4.51
.38	.46	.63	.75	.98	1.15	1.45	1.73	2.18	2.68	3.33	4.62
.38	.46	.63	.76	.98	1.17	1.45	1.74	2.19	2.68	3.38	4.64
.38	.46	.64	.77	.99	1.17	1.46	1.74	2.21	2.69	3.39	4.69
.39	.46	.64	.77	.99	1.18	1.46	1.74	2.24	2.71	3.45	4.73
.39	.46	.64	.78	1.01	1.19	1.47	1.76	2.24	2.71	3.45	4.77
.39	.47	.64	.78	1.01	1.21	1.47	1.77	2.25	2.74	3.55	4.77
.39	.47	.64	.78	1.01	1.21	1.49	1.77	2.26	2.75	3.55	4.79
.39	.47	.65	.79	1.02	1.23	1.49	1.78	2.26	2.75	3.56	4.79
.39	.48	.65	.80	1.03	1.23	1.49	1.78	2.28	2.81	3.59	5.03
.39	.48	.66	.81	1.03	1.23	1.49	1.79	2.29	2.82	3.70	5.09
.39	.48	.66	.82	1.03	1.23	1.52	1.81	2.31	2.82	3.70	5.19
.41	.48	.67	.83	1.03	1.24	1.53	1.83	2.32	2.83	3.70	5.24
.41	.49	.67	.84	1.03	1.25	1.53	1.85	2.32	2.85	3.75	5.37
.41	.49	.67	.85	1.03	1.25	1.53	1.87	2.34	2.88	3.76	5.52
.41	.50	.67	.85	1.04	1.25	1.54	1.90	2.34	2.89	3.79	5.62
.41	.50	.67	.85	1.04	1.26	1.54	1.90	2.35	2.94	3.79	5.79
.41	.52	.68	.86	1.04	1.27	1.55	1.92	2.36	2.95	3.80	6.06
.41	.52	.68	.86	1.04	1.29	1.56	1.93	2.36	2.97	3.81	6.06
.41	.53	.69	.87	1.04	1.30	1.56	1.93	2.37	2.98	3.86	6.26
.41	.53	.69	.88	1.04	1.31	1.57	1.94	2.40	2.98	3.89	6.78
.41	.53	.69	.88	1.05	1.31	1.57	1.95	2.41	2.98	3.91	8.19
.41	.53	.70	.89	1.05	1.32	1.58	2.00	2.44	3.00	3.96	8.55
13.55	17.78	23.77	29.81	37.55	44.85	55.17	66.93	84.00	103.56	131.36	190.47
0.36	0.46	0.62	0.78	0.99	1.18	1.45	1.76	2.21	2.73	3.46	5.01

TABLE No. 4.

Croton River. Drainage Area 338.8 Square Miles.
Monthly Data. 1868 to 1905 Inclusive.

Comparison of Available Flow Averaged by Three Different Methods.

A. Average flow in second feet per square mile.
B. Massed flow.
C. Average flow of months equal to or less than development "A."
D. Average available flow for the year with development "A."

	Months.	Chronologically.				Order of Magnitude by Years.				Order of Magnitude of Whole Term.			
		A	B	C	D	A	B	C	D	A	B	C	D
1	July.....	.72	.72	.72	.72	.51	.51	.51	.51	.36	.36	.36	.36
2	Sept.....	.92	1.64	.82	.90	.64	1.15	.58	.63	.46	.82	.41	.45
3	June.....	1.00	2.64	.88	.97	.73	1.88	.63	.70	.82	1.44	.48	.59
4	Aug......	1.05	3.69	.92	1.01	.85	2.73	.68	.79	.78	2.22	.55	.71
5	Oct......	1.10	4.79	.96	1.04	1.01	3.74	.75	.90	.99	3.21	.64	.85
6	Nov.....	1.37	6.16	1.03	1.20	1.23	4.97	.83	1.03	1.18	4.39	.73	.96
7	May.....	1.67	7.83	1.12	1.35	1.43	6.40	.91	1.13	1.45	5.84	.83	1.09
8	Dec.	1.83	9.66	1.21	1.42	1.79	8.19	1.02	1.28	1.76	7.60	.95	1.22
9	Jan......	2.26	11.92	1.32	1.56	2.14	10.33	1.15	1.39	2.21	9.81	1.09	1.37
10	Feb.	2.72	14.63	1.46	1.67	2.70	13.03	1.30	1.54	2.73	12.54	1.25	1.50
11	April....	2.80	17.43	1.58	1.69	3.39	16.42	1.49	1.65	3.46	16.00	1.45	1.62
12	March...	3.59	21.02	1.75	1.75	4.60	21.02	1.75	1.75	5.01	21.01	1.75	1.75

TABLE No. 5.

Croton River, New York.
Thirty-Eight Years, 1869 to 1905 Inclusive. Drainage Area 338.8 Square Miles.

Original Data Calculated Monthly.

A. Flow in cubic feet per second per square mile.
B. Number of months this flow occurred in the whole term of years.
C. Number of months this flow and all lower flows combined occurred.
D. Product of each flow by the number of months it occurred (A × B).
E. Sum of products for this flow and all lower flows.
F. Average number of days per year this flow occurred in whole term of years (C × .8 = F).
G. Average flow of all days below and including this flow.
H. Average flow for the whole year with development equal to this flow,

$$\frac{(365 - F)\ A + (F \times G)}{365}$$

A	B	C	D	E	F	G	H
.10	1	1	.10	.10	1	.10	.10
.16	1	2	.16	.26	2	.13	.16
.26	1	3	.26	.52	3	.17	.26
.27	2	5	.54	1.06	4	.21	.27
.28	1	6	.28	1.34	5	.22	.28

A	B	C	D	E	F	G	H
.29	1	7	.29	1.63	6	.23	.29
.30	1	8	.30	1.93	7	.24	.30
.33	2	10	.66	2.59	8	.26	.33
.35	1	11	.35	2.94	9	.27	.35
.36	2	13	.72	3.66	10	.28	.36
.37	2	15	.74	4.40	12	.29	.37
.38	4	19	1.52	5.92	15	.31	.38
.39	8	27	3.12	9.04	22	.33	.39
.41	11	38	4.51	13.55	30	.35	.40
.42	3	41	1.26	14.81	33	.36	.41
.43	4	45	1.72	16.53	36	.37	.42
.44	4	49	1.76	18.29	39	.37	.43
.45	3	52	1.35	19.64	41	.38	.44
.46	7	59	3.22	22.86	47	.39	.45
.47	3	62	1.41	24.27	49	.39	.46
.48	4	66	1.92	26.19	53	.40	.47
.49	2	68	.98	27.17	54	.40	.48
.50	2	70	1.00	28.17	56	.40	.49
.52	2	72	1.04	29.21	57	.41	.50
.53	4	76	2.12	31.33	60	.41	.51
.54	3	79	1.62	32.95	63	.42	.52
.55	4	83	2.20	35.15	66	.42	.53
.56	2	85	1.12	36.27	68	.43	.54
.57	1	86	.57	36.84	69	.43	.55
.59	1	87	.59	37.43	70	.43	.56
.61	1	88	.61	38.04	71	.43	.57
.62	2	90	1.24	39.28	72	.44	.58
.63	4	94	2.52	41.80	75	.44	.59
.64	5	99	3.20	45.00	79	.45	.60
.65	2	101	1.30	46.30	81	.46	.61
.66	2	103	1.32	47.62	82	.46	.61
.67	5	108	3.35	50.97	86	.47	.62
.68	2	110	1.36	52.33	88	.48	.63
.69	3	113	2.07	54.40	90	.48	.64
.70	2	115	1.40	55.80	92	.49	.64
.71	1	116	.71	56.51	93	.49	.65
.72	3	119	2.16	58.67	95	.49	.65
.73	1	120	.73	59.40	96	.50	.66
.74	6	126	4.44	63.84	100	.51	.68
.75	5	131	3.75	67.89	105	.52	.68
.76	1	132	.76	68.35	106	.52	.69
.77	2	134	1.54	69.89	107	.52	.70
.78	3	137	2.34	72.23	110	.53	.70
.79	1	138	.79	73.02	110	53	.72
.80	1	139	.80	73.82	111	.53	.72
.81	1	140	.81	74.63	112	.53	.72
.82	1	141	.82	75.45	113	.54	.73
.83	1	142	.83	76.38	114	.54	.74
.84	1	143	.84	77.12	115	.54	.75
.85	3	146	2.55	79.67	117	.55	.75
.86	2	148	1.72	81.39	118	.55	.76
.87	1	149	.87	82.26	119	.55	.76
.88	2	151	1.76	84.02	121	.56	.77

A	B	C	D	E	F	G	H
.89	1	152	.89	84.91	122	.56	.78
.91	3	155	2.73	87.64	124	.57	.79
.92	3	158	2.76	90.40	126	.57	.80
.93	1	159	.93	91.33	127	.57	.80
.94	2	161	1.88	93.21	129	.58	.82
.95	3	164	2.85	96.06	131	.59	.82
.96	1	165	.96	97.02	132	.59	.83
.97	1	166	.97	97.99	133	.60	.83
.98	4	170	3.92	101.91	136	.60	.84
.99	2	172	1.98	103.89	138	.60	.84
1.01	3	175	3.03	106.92	140	.60	.85
1.02	7	176	1.02	107.94	141	.60	.86
1.03	6	182	6.18	114.12	145	.63	.87
1.04	6	188	6.24	120.36	150	.64	.88
1.05	2	190	2.10	122.46	152	.64	.88
1.06	2	192	2.12	124.58	154	.65	.89
1.07	1	193	1.07	125.65	154	.65	.89
1.08	3	196	3.24	129.89	157	.66	.90
1.09	1	197	1.09	129.98	158	.66	.90
1.10	2	199	2.20	132.18	159	.66	.91
1.11	3	202	3.33	135.51	162	.67	.91
1.12	1	203	1.12	136.63	162	.67	.92
1.13	1	204	1.13	137.76	163	.68	.93
1.15	3	207	3.45	141.21	166	.68	.94
1.17	2	209	2.34	143.55	167	.69	.95
1.18	1	210	1.18	144.73	168	.69	.95
1.19	1	211	1.19	145.92	169	.69	.96
1.21	2	213	2.42	148.34	170	.70	.97
1.23	4	217	4.92	153.26	174	.70	.98
1.24	1	218	1.24	154.50	174	.70	.98
1.25	3	221	3.75	158.25	177	.72	.99
1.26	1	222	1.26	159.51	177	.72	1.00
1.27	1	223	1.27	160.78	178	.72	1.00
1.29	1	224	1.29	162.07	179	.72	1.01
1.30	1	225	1.30	163.37	180	.73	1.02
1.31	2	227	2.62	165.99	181	.73	1.02
1.32	1	228	1.32	167.31	182	.73	1.03
1.33	3	231	3.99	177.30	185	.74	1.03
1.34	3	234	4.12	175.32	187	.75	1.04
1.35	1	235	1.35	176.67	188	.75	1.04
1.36	3	238	4.08	180.75	190	.76	1.05
1.38	2	240	2.76	183.51	192	.76	1.05
1.39	1	241	1.39	184.90	193	.77	1.06
1.42	2	243	2.84	187.74	194	.78	1.06
1.44	1	244	1.44	189.18	195	.78	1.07
1.45	2	245	2.90	192.08	197	.78	1.09
1.46	2	248	2.92	195.00	198	.79	1.10
1.47	2	250	2.94	197.94	200	.79	1.10
1.49	4	254	5.96	203.90	203	.80	1.11
1.52	1	255	1.52	205.42	204	.81	1.12
1.53	3	258	4.59	210.01	206	.81	1.12
1.54	2	260	3.08	213.09	208	.82	1.13
1.55	1	261	1.55	215.64	209	.82	1.13

A	B	C	D	E	F	G	H
1.56	2	263	3.12	218.76	210	.83	1.14
1.57	2	265	3.14	221.90	212	.84	1.14
1.58	1	266	1.58	222.48	213	.84	1.15
1.59	1	267	1.59	224.07	214	.84	1.15
1.62	3	270	4.86	228.93	216	.85	1.16
1.63	1	271	1.63	230.56	217	.85	1.17
1.64	1	272	1.64	232.20	217	.85	1.17
1.65	2	274	3.30	235.50	219	.86	1.18
1.66	1	275	1.66	237.16	220	.86	1.18
1.67	3	278	5.01	242.17	222	.87	1.18
1.69	2	280	3.28	245.45	224	.88	1.19
1.71	1	281	1.71	247.16	225	.88	1.20
1.72	1	282	1.72	248.88	225	.88	1.20
1.73	1	283	1.73	250.61	226	.89	1.21
1.74	3	286	5.22	255.83	228	.89	1.21
1.76	1	287	1.76	257.59	230	.90	1.22
1.77	2	289	3.54	261.13	231	.90	1.22
1.78	2	291	3.56	264.69	233	.91	1.23
1.79	1	292	1.79	266.48	233	.91	1.23
1.81	1	293	1.81	268.29	234	.92	1.23
1.83	1	294	1.83	270.12	235	.92	1.24
1.85	11	295	1.85	270.97	236	.92	1.25
1.87	1	296	1.87	272.84	237	.92	1.25
1.90	2	298	3.80	276.64	238	.93	1.27
1.92	1	299	1.92	278.56	239	.93	1.27
1.93	2	301	3.86	282.42	241	.94	1.28
1.94	1	302	1.94	284.36	242	.94	1.28
1.95	1	303	1.95	286.31	242	.94	1.28
2.00	2	305	4.00	290.31	244	.95	1.30
2.01	2	307	4.02	294.33	246	.96	1.30
2.04	1	308	2.04	296.37	246	.96	1.31
2.07	2	310	4.14	300.51	248	.97	1.32
2.08	1	311	2.08	302.59	249	.97	1.32
2.09	4	315	8.36	311.95	252	.99	1.33
2.10	1	316	2.10	314.05	253	.99	1.33
2.12	2	318	4.24	318.29	254	1.00	1.34
2.13	1	319	2.13	320.42	255	1.00	1.34
2.17	1	320	2.17	322.59	256	1.01	1.35
2.18	1	321	2.18	324.77	257	1.01	1.36
2.19	1	322	2.19	326.96	258	1.01	1.36
2.21	1	323	2.21	329.17	258	1.02	1.37
2.24	2	325	4.48	333.65	260	1.03	1.37
2.25	1	326	2.25	335.90	261	1.03	1.37
2.26	2	328	4.52	340.42	262	1.04	1.38
2.28	1	329	2.28	342.70	263	1.04	1.39
2.29	1	330	2.29	344.99	264	1.05	1.39
2.31	1	331	2.31	347.30	265	1.05	1.39
2.32	2	333	4.64	351.94	266	1.06	1.40
2.34	2	335	4.68	356.62	268	1.06	1.40
2.35	1	336	2.35	358.97	269	1.07	1.40
2.36	2	338	4.72	363.69	270	1.08	1.41
2.37	1	339	2.37	366.06	271	1.08	1.41
2.40	1	340	2.40	368.46	272	1.08	1.42

A	B	C	D	E	F	G	H
2.41	1	341	2.41	370.87	273	1.09	1.42
2.44	2	343	4.88	375.75	274	1.09	1.43
2.45	1	344	2.45	378.20	275	1.10	1.43
2.47	1	345	2.47	380.67	276	1.10	1.44
2.49	2	347	4.98	385.65	278	1.11	1.44
2.54	1	348	2.54	388.19	278	1.12	1.45
2.55	1	349	2.55	390.74	279	1.12	1.46
2.57	1	350	2.57	393.31	280	1.12	1.46
2.60	1	351	2.60	395.91	281	1.12	1.46
2.62	2	353	5.24	401.15	282	1.13	1.47
2.64	1	354	2.64	403.79	283	1.14	1.48
2.65	1	355	2.65	406.44	284	1 14	1.48
2.67	2	357	5.34	411.78	286	1.15	1.48
2.68	3	360	8.04	419.82	288	1.16	1.48
2.69	1	361	2.69	422.51	289	1.17	1.49
2.71	2	363	5.42	427.93	290	1.17	1.49
2.74	1	364	2.74	430.67	291	1.18	1.50
2.75	2	366	5.50	436.17	293	1.19	1.50
2.81	1	367	2.81	438.98	294	1.19	1.51
2.82	2	369	5.64	444.62	295	1.20	1.51
2.83	1	370	2.83	447.45	296	1.20	1.51
2.85	1	371	2.85	450.30	297	1.21	1.52
2.88	1	372	2.88	453.18	298	1.21	1.52
2.89	1	373	2.89	456.07	298	1.21	1.52
2.94	1	374	2.94	459.01	299	1.21	1.52
2.95	1	375	2.95	461.96	300	1.23	1.54
2.97	1	376	2.97	464.93	301	1.23	1.54
2.98	3	379	8.94	473.87	303	1.23	1.54
3.00	1	380	3.00	476.87	304	1.25	1.54
3.02	1	381	3.02	479.89	305	1.26	1.55
3.04	2	383	6.08	485.97	306	1.27	1.56
3.07	2	385	6.14	492.11	308	1.27	1.56
3.11	1	386	3.11	495.22	309	1.28	1.56
3.14	1	387	3.14	498.36	310	1.28	1.56
3.15	2	389	6.30	504.66	311	1.29	1.57
3.17	1	390	3.17	507.83	312	1.29	1.58
3.24	1	391	3.24	511.07	313	1.30	1.58
3.28	1	392	3.28	514.35	314	1.31	1.59
3.29	1	393	3.29	517.64	314	1.31	1.59
3.30	1	394	3.30	520.94	315	1.32	1.59
3.31	2	396	6.62	527.56	317	1.33	1.59
3.33	1	397	3.33	530.89	318	1.33	1.59
3.38	1	398	3.38	534.27	318	1.34	1.60
3.39	1	399	3.39	537.66	319	1.34	1.60
3.45	2	401	6.90	544.56	321	1.36	1.61
3.55	2	403	7.10	551.66	322	1.37	1.63
3.56	1	404	3.56	555.22	323	1.37	1.63
3.59	1	405	3.59	558.81	324	1.38	1.63
3.70	3	408	11.10	569.91	326	1.39	1.64
3.75	1	409	3.75	573.66	327	1.40	1.65
3.76	1	410	3.76	577.42	328	1.41	1.65
3.79	2	412	7.58	585.00	330	1.42	1.65
3.80	1	413	3.80	588.80	330	1.42	1.65

A	B	C	D	E	F	G	H
3.81	1	414	3.81	592.61	331	1.43	1.65
3.86	1	415	3.86	596.47	332	1.43	1.65
3.89	1	416	3.89	600.36	333	1.44	1.66
3.91	1	417	3.91	604.27	334	1.45	1.66
3.96	1	418	3.96	608.23	334	1.45	1.66
4.03	2	420	8.06	616.29	336	1.47	1.67
4.06	1	421	4 06	620.35	337	1.47	1.67
4.08	2	423	8.16	628.51	338	1.48	1.67
4.13	1	424	4.13	632.64	339	1.49	1.68
4.22	2	426	8.44	641.08	341	1.50	1.68
4.25	1	427	4.25	645.33	342	1.51	1.68
4.32	1	428	4.32	649.65	342	1.52	1.69
4.34	1	429	4.34	653.99	343	1.52	1.69
4.35	1	430	4.35	658.34	344	1.53	1.69
4.41	1	431	4.41	662.75	345	1.54	1.70
4.42	1	432	4.42	667.17	346	1.54	1.70
4.47	1	433	4.47	671.64	346	1.55	1.70
4.51	1	434	4.51	676.15	347	1.56	1.71
4.62	1	435	4.62	680.77	348	1.56	1.71
4.64	1	436	4.64	685.41	349	1.57	1.71
4.69	1	437	4.69	690.10	350	1.58	1.71
4.73	1	438	4.73	694.83	350	1.58	1.71
4.77	2	440	9.54	704.37	352	1.59	1.71
4.79	2	442	9.58	713.95	354	1.61	1.71
5.03	1	443	5.03	718.98	354	1.61	1.71
5.09	1	444	5.09	724.07	355	1.62	1.71
5.19	1	445	5.19	729.26	356	1.63	1.71
5.24	1	446	5.24	734.50	357	1.64	1.72
5.37	1	447	5.37	739.87	358	1.65	1.72
5.52	1	448	5.52	745.39	358	1.66	1.73
5.62	1	449	5.62	751.01	359	1.67	1.74
5.79	1	450	5.79	756.80	360	1.68	1.74
6.06	2	452	12.12	768.92	362	1.70	1.74
6.26	1	453	6.26	775.18	362	1.71	1.75
6.78	1	454	6.78	781.96	363	1.72	1.75
8.19	1	455	8.19	790.15	364	1.73	1.75
8.55	1	456	8.55	798.70	365	1.75	1.75

TABLE No. 7.

CONNECTICUT RIVER, HOLYOKE, MASS.

NINETEEN YEARS, 1881 TO 1899 INCLUSIVE. DRAINAGE AREA 8 660 SQUARE MILES.

A. Cubic feet per second per square mile for twenty-four hours that wheels, etc., are designed for.
B. Cubic feet per second per square mile, twenty-four hours' flow in ten hours.
C. Horse-power per foot fall per square mile corresponding with A (80 per cent. efficiency).
D. Horse-power per foot fall per square mile corresponding with B (80 per cent. efficiency).
E. Average number of days yearly on which flows A and B and powers C and D occurred.
F. Average number of days yearly on which flows less than A and B and powers less than C and D occurred.
G. Average flow for twenty-four hours on the days when flow was less than A.
H. Average flow using twenty-four hours' flow in ten hours on the days when flow was less than B.
J. Average horse-power per foot mile for twenty-four hours on the days when flow was less than A.
K. Average horse-power per foot mile using twenty-four hours' flow in ten hours on the days when flow was less than B.
L. Average available flow of full year, twenty-four hours per day with development A.
M. Average available flow of full year using twenty-four hours in ten hours with development B.
N. Average available power of full year, twenty-four hours per day, with development A.
O. Average available power of full year using twenty-four hours in ten hours with development B.
P. Percentage that available flow and power bear to the development A, B, C, and D.

C. F. P. S. P. S. M.		H. P. per Foot Mile.		Number of Days.		Average Flow Short Days.		Average Power Short Days.		Average Flow Available.		Average Power Available.		Per Cent. Available.
24 Hrs. A	24 in 10. B	24 Hrs. C	24 in 10. D	Full. E	Short. F	24 Hrs. G	24 in 10. H	24 Hrs. J	24 in 10. K	24 Hrs. L	24 in 10. M	24 Hrs. N	24 in 10. O	P
0.2	.48	.018	.043	311	1	.19	.46	.018	.042	.20	.48	.018	.044	100
0.3	.72	.027	.065	301	11	.26	.62	.024	.057	.29	.70	.026	.064	98
0.4	.96	.036	.087	260	52	.33	.79	.030	.072	.39	.94	.035	.085	97
0.5	1.20	.046	.109	227	85	.38	.91	.034	.083	.47	1.13	.043	.103	94
0.6	1.44	.055	.131	201	111	.42	1.01	.038	.092	.54	1.30	.049	.117	90
0.7	1.68	.064	.153	181	131	.46	1.10	.042	.100	.60	1.44	.055	.131	86
0.8	1.92	.073	.175	164	148	.49	1.18	.045	.107	.65	1.56	.059	.142	81
0.9	2.16	.082	.197	146	166	.53	1.27	.048	.115	.70	1.68	.064	.153	78
1.0	2.40	.091	.218	133	179	.56	1.34	.051	.122	.75	1.80	.068	.164	75
1.1	2.64	.100	.240	121	191	.59	1.42	.054	.129	.79	1.90	.072	.173	72
1.2	2.88	.109	.262	110	202	.62	1.49	.056	.135	.82	1.97	.075	.179	68
1.3	3.12	.118	.284	102	210	.65	1.56	.059	.142	.86	2.06	.078	.187	66
1.4	3.36	.127	.306	93	219	.68	1.63	.062	.148	.89	2.14	.081	.194	64
1.5	3.60	.136	.327	85	227	.70	1.68	.064	.153	.92	2.21	.084	.201	61
1.6	3.84	.146	.349	77	235	.73	1.75	.066	.159	.94	2.26	.086	.205	59
1.7	4.08	.155	.371	71	241	.76	1.82	.069	.165	.97	2.33	.088	.213	57

Formulated by Chandler & Palmer, Norwich, Conn., from data furnished by A. F. Sickman, hydraulic engineer, Holyoke, Mass.

Rafter in his valuable Water Supply and Irrigation Paper No. 80 says: "What is wanted is a clear statement of the minimum together with the longest period such minimum may be expected to occupy."

This is useful only for a development equal to the minimum flow. It seems to the writer that what is wanted is "The *duration* of *every* flow."

This is what Table No. 6 gives us for the Connecticut at Holyoke. The table is so arranged as to give the available flow at any development each year, as well as for the whole term of nineteen years. In no case is a small flow averaged with a larger flow. Days are averaged, not flows.

In order to make the data of convenient application, the average duration of each flow for the whole term, for different developments from 0.2 second feet per square mile to 1.7 second feet per square mile, has been calculated, and shown in Table No. 7.

In column A has been placed each flow varying by .1 for twenty-four hours, and in column B the same flow concentrated in ten hours. Columns C and D give the same flows in terms of horse power per foot mile with 80 per cent. efficiency. Columns E and F give the average number of short and full days at the developments indicated by A and B. Columns G and H give the average flow of the short days. The difference between A and G and between B and H give the average auxiliary power needed at any development. Columns J and K give the power corresponding to the flow in G and H; columns L and M give the average flow, and N and O the average power available throughout the year at any given development A.

The difference between N and O, as the case may be, and A is the average amount of auxiliary power needed at any development A.

Perhaps the last column P is as useful as any, as it gives at any development the average percentage of that development that is available throughout the year on the Connecticut River, or similar stream.

Table No. 8 for the purpose of comparison, shows the average number of full days and average available percentage of flow and power on several other streams.

TABLE No. 8.

Flow of Streams.

Connecticut River at Holyoke. Calculations made daily.
Merrimac River at Lawrence. Calculations made weekly.
Sudbury River, near Boston. Calculations made monthly.
Nashua River at Clinton. Calculations made monthly.
Croton River near New York. Calculations made monthly.

Cubic Feet per Sec. per Sq. Mile	Connecticut. 19 Years. 1881 to 1899. 8 660 Sq. Miles.		Merrimac. 11 Years. 1890 to 1900. 4 553 Sq. Miles.		Sudbury. 19 Years. 1881 to 1899. 75 Sq. Miles.		Nashua. 9 Years. 1897 to 1905. 119 Sq. Miles.		Croton. 19 Years. 1881 to 1899. 338.8 Sq. Miles.	
	Full Days	Per cent ava'lble	Full Days	Per cent ava'lble	Full Days	Per cent ava'lble	Full Days	Per cent ava'lble	Full Days	Per cent ava'lble
.1	312	100	312	100	304	99	312	100	312	100
.2	311	100	312	100	275	96	309	100	312	100
.3	301	98	311	100	258	92	309	99	312	100
.4	260	97	299	99	234	89	289	98	304	100
.5	227	94	261	97	218	86	272	96	281	98
.6	201	90	230	94	208	83	243	94	270	96
.7	181	86	205	91	190	80	228	91	256	95
.8	164	81	188	88	186	78	208	89	229	93
.9	146	78			180	75	194	87	215	90
1.0	133	75			170	73	185	84	195	87
1.1	121	72			162	71	173	81	177	85
1.2	110	68			158	70	170	79	169	83
1.3	102	66			152	69	162	77	160	80
1.4	93	64			145	67	153	75	148	78
1.5	85	61			137	65	142	73	138	76
1.6	77	59			127	64	133	70	134	74
1.7	71	57			122	63	130	68	126	72

The above "full days" were obtained by dividing the total number of days each flow occurred during the whole term of years by the number of years to obtain the average number of days each flow was available.

The percentage was obtained by adding the products of all flows by the number of days they occurred and dividing the sum by the products of the given development multiplied by the whole number of working days in the year.

Computed by Chandler & Palmer, 161 Main Street, Norwich, Conn.

Sudbury and Croton are shown for the same nineteen years as are covered by the Holyoke data. Merrimac and Nashua data for the same years are not available.

It should be remembered in comparing these stream flows, that the Holyoke data are from computations made daily, the Merrimac weekly, and the Sudbury, Nashua, and Croton monthly. It should also be remembered that there is a wide divergence in the size of the drainage areas.

There are, of course, plenty of modifications necessary in applying these figures to streams of a different character and under varying circumstances, but it is hoped that the data and the method of their arrangement may be of some use to some one.

DISCUSSION.

THE PRESIDENT. Mr. Chandler's paper is open for discussion. We should like to hear from Mr. Mixer.

MR. CHARLES A. MIXER.* Gentlemen, I have been much interested in this paper and in these (to me) new methods of analyzing river discharges. Not knowing in advance what was to be presented, I am not prepared to discuss them; but I am certain that I shall apply some of the new things heard to my own records.

These variable discharges should be examined from every point of view and by every method of arrangement, but their natural order should never be discarded after re-arranging them in any other order. On a river, with storage and regulation, and in a latitude where the low-water conditions are divided between two seasons, viz., September and February, and where water is used in the same amount throughout the twenty-four hours a day, the natural order of the discharges remains the best. Simply plotting the daily discharges as they occur is a help to easier and more comprehensive study of them.

I will state for those who may not know, that I am at Rumford Falls, Maine, on the Androscoggin River, with its great Rangeley Lakes storage. The records of the daily discharge here for fifteen years have been published in the Water Supply Papers.

MR. H. K. BARROWS.† Mr. President and Gentlemen, I agree with Mr. Mixer that a paper of this sort should be studied somewhat before discussion is attempted. Certainly Mr. Chandler has presented these data in a new and a very interesting way.

There has been some question in my mind whether or not data of this kind should not also be presented in the original form to be of the most value for all purposes. For a given plant, such as on the Connecticut at Holyoke, the data of flow as arranged by Mr. Chandler are certainly very useful, and one can almost tell at a glance what wheel capacity is warranted, and whether or not it can be profitably increased. If he is dealing with a similar situation on some other river where such data can properly be applied, this form is also convenient.

* Hydraulic Engineer, Rumford Falls, Me.
† Hydraulic and Sanitary Engineer, Boston, Mass.

Where the storage of water at points above the power site is to be a factor in the distribution of run-off, and perhaps further development of storage is contemplated, we especially desire the natural flow of a river as it occurred. In such investigations the tables as arranged by Mr. Chandler cannot be used, as it is evidently incorrect to consider as successive monthly or weekly discharges those occurring at widely varying times. Thus in a given case, the driest month might perhaps be September, and the next driest January, and it is evidently misleading in computations involving storage to consider monthly discharges in this order.

The reports of the United States Geological Survey usually give run-off in the form of monthly minimum, maximum, and mean discharge, although in some cases the daily discharge is also included. On most of our New England streams the flow during medium and low water times is much affected by pondage at privileges further upstream, and in some cases by storage reservoirs, and the flow on any given day based on the usual gage readings may diverge widely from both the true daily mean for that day and the natural flow of the river for that day. For this reason the *week* is a better unit of time for which to consider run-off, as this is a sufficient period for daily gage height errors to compensate, and it is also the usual cycle of pondage and storage variations.

It seems to me that the tables shown by Mr. Chandler could be with profit constructed on the basis of the week, especially during the low-water portion, and I hope that he will be able to include in his paper the *daily flow* as observed, and upon which his tables are based, to permit of this more extended analysis. The *daily* flow of the Connecticut at Holyoke has never been published by the United States Geological Survey, although the monthly mean, maximum, and minimum has been given, scattered through several reports, covering the period discussed by Mr. Chandler.

The President. Mr. Hale, we should like to hear from you.

Mr. Richard A. Hale.* I think, as the previous speaker has said, that a study of the paper is very desirable before discussing it, because there are so many details in connection with it.

One reason that I adopted on the Merrimac River the unit of

* Hydraulic Engineer, Lawrence, Mass.

the week for the average flow was on account of the storage reservoirs above us at Lowell, Manchester, and at various other points, as it appeared to give a better index of the flow of the river than taking it for a single day. For instance, on Sundays during a dry season the water is retained at various dams along the river. The driest day in the year, from the actual records as the Geological Survey used to give them, would give perhaps a flow of 50 cubic feet per second from 4 000 square miles, which is inaccurate; it means simply that the water is held back, and is not the normal flow. For this reason, the average of a week eliminates to a great extent these irregularities of storage of water.

In regard to the averages, taking the average by months, it produces a smooth outflow which is very misleading, and I have brought a diagram here which was used at Springfield in the paper on "Water Rights" and is familiar to many of you.* It was used in one of the Nashua River cases, in which the flow was worked up for each individual day for a period of years. This was for one year and it shows the extreme variations. The scale is indicated on the side of diagram. The variation in January and February is from 100 horse-power up to 500 horse-power in about two or three days, owing to unusual freshets at this time.

Now, taking the average of a series of months, you might get apparently a very excellent water-power, when, as a matter of fact, there might be a large freshet that would run off in a short time and there would be a series of days of low water when you would derive very small advantage from water-power.

During the dry months, when a very low flow occurs, we have an example in November where the average would indicate a large power. At the commencement of the month there was only 100 horse-power, and then sudden rains increased the flow through November and December. The monthly average would show a large uniform power, which shows the care that must be taken in using averages in connection with water-power.

Considering also a large development of 425 horse-power at this site, although it might be obtained during the first four or five months, there would be this large gap of perhaps 300 horse-power, which would have to be supplied by steam, so a steam

* See JOURNAL, September, 1907, page 257.

plant would have to be maintained in connection with the water-plant to maintain constant power.

The whole system of averages must be carefully considered in connection with water-power, and certain allowances made, both for sudden storms, where the water wastes over the dam, and the amount of pondage, and the use of water by parties further up the stream, as the total flow during dry months is not entirely available. But I think the whole system of averaging the minimum flows is the best method, and not averaging by the calendar months; it gives a better index of flow of streams than by any other method.

If a man has a steam engine and a water wheel running together, and connected by a clutch, by which the wheel can be readily disconnected while running the mill, advantage can be taken of varying flows of water with little trouble. If, however, there are such connections that gears have to be moved on the wheel, and changes made at noon or night, when the mill is stopped, the extra work involved may not be compensated for by the use of water. In such cases the available power is not all used, and waste over the dam would naturally follow.

Mr. Charles W. Sherman.* Mr. President, in considering the run-off records of our water supply streams, such as the Sudbury and the Croton, it should always be distinctly borne in mind that the flow is, as Mr. Barrows has put it, in a decidedly artificial condition.

The State Board of Health of Massachusetts has computed from original records the weekly run-off of the Sudbury and Nashua rivers, and published it each year in its yearly report. My own opinion has always been that that was hardly warranted by the conditions of gaging. Those watersheds contain very large storage reservoirs; in some cases during the drier months one-tenth foot of storage would mean the run-off of perhaps a whole month. It is impossible to measure the *exact* height of the water in those reservoirs, and even if that were possible the change of storage represented by a change of height in the reservoirs could be determined only approximately. And as those figures form an important element in computing the run-off of the stream,

* Principal Assistant Engineer, with Metcalf & Eddy, Boston, Mass.

the quantity flowing in a single day (which could be computed mathematically from the records, as well as the quantity for a month) would really mean nothing whatever. My feeling has been that the quantity computed for the week, although not subject to anything like the same percentage of error as would be that for a single day, would still have to be taken with a grain of salt. I think in cases like that, the month is the smallest unit of time that we can logically use.

Of course, in making use of such records, the engineer must bear in mind that the average flow of a month would be exceeded during the month, and there would also be days when the flow was very much less than the average; and he would have to use his judgment in estimating what the probable daily minimum or daily maximum would be.

I think that applies to practically all of the small streams that have been used for water supply purposes. In the case of water-power streams the actual quantity of water flowing in the stream is the main element of the situation, and storage does not cut nearly so large a figure, so that it can frequently be neglected.

Mr. Chandler. The situation in Holyoke is unique in various ways. In the first place, they no longer are making these calculations, on account of the fact that the new dam and the old dam are so near together that it seems impracticable to measure the flow, so this nineteen-year record is all that we are likely to have in relation to Holyoke.

Again, the Holyoke tables show only the working days of the year, omitting Sundays; and the effect of storage and storage reservoirs on the streams is included, because what is really measured is what you get having those reservoirs and having the advantage of them.

In relation to the monthly data, I do not see how it could be expected that ordinary water-works data should be computed any oftener than monthly, and for ordinary water-works purposes I don't see why that isn't all that is needed. But it does not seem applicable for power purposes. Of course we have had to use it for power purposes all along, but it does not seem so practicable as daily or weekly observations on these larger streams.

And another thing: an average, even when calculated in the

way I have suggested, gives too large a result, yet the manufacturer, in diversion cases, naturally wants the whole three hundred and sixty-five days, Sundays and all, and, failing this, he is satisfied with figures which are averaged, perhaps monthly, or in order of magnitude.

Now, to apply the principle in question is simply going somewhat further in the right direction without any danger of getting too far, because you can't get beyond the fact that the shortest distance between two points is a straight line, and all these other things are more or less incorrect.

(*By letter*, November 30, 1907.) Regarding the idea of arranging stream flow data in order of magnitude of whole term instead of each year, MR. H. G. SCHOFIELD, civil engineer of Bridgeport Conn., writes as follows: "I have myself for several years used a formula which must produce practically the same results, but with this difference, that I have used the twenty-year run-off of the Connecticut River at Holyoke as observed in ten-day periods, beginning with the least flow for that time, regardless of the date, and following it up by successive periods of the same length of time."

TABLE No. 9.

Showing Run-off in Second-Feet per Square Mile of Watershed for Each Tenth Day, beginning with the Least Day's Discharge, Regardless of the Time of Occurrence.

As deduced by H. G. Schofield, C.E., Bridgeport, Conn., from the table of Connecticut River flows at Holyoke, Mass., by Clemens Herschel, C.E., published in Proceedings of the American Society of Civil Engineers, November, 1906, page 928.

Column 1. No. of Period.	Column 2. Run-off in 24 Hrs.	Column 3. Run-off per Sq. M. per Sec.	Column 4. Run-off. Average of Two Periods.	Column 5. Horse-power at 80% Efficiency.
1st	2 607	0.32	0.34	0.030909
2d	2 935	0.36	0.375	0.0340909
3d	3 175	0.39	0.408	0.0370909
4th	3 470	0.426	0.441	0.0400909
5th	3 710	0.455	0.471	0.0428181
6th	3 977	0.488	0.501	0.045554
7th	4 200	0.515	0.527	0.047909
8th	4 392	0.539	0.552	0.050181
9th	4 602	0.565	0.578	0.052545
10th	4 815	0.591	0.610	0.055454
11th	5 122	0.629	0.651	0.059181
12th	5 470	0.672	0.692	0.062909
13th	5 805	0.712	0.731	0.066454
14th	6 120	0.751	0.769	0.069909
15th	6 425	0.788	0.807	0.073363
16th	6 727	0.826	0.839	0.076273
17th	7 135	0.851	0.889	0.080818
18th	7 557	0.928	0.957	0.087000
19th	8 037	0.987	1.017	0.092454
20th	8 537	1.048	1.082	0.098363
21st	9 085	1.115	1.150	0.104542
22d	9 652	1.185	1.225	0.111363
23d	10 312	1.266	1.301	0.118273
24th	11 042	1.356	1.397	0.12700
25th	11 710	1.438	1.483	0.134828
26th	12 452	1.529	1.584	0.14400
27th	13 352	1.639	1.708	0·155273
28th	14 470	1.777	1.869	0.16990
29th	15 982	1.962	2.046	0.18600
30th	17 355	2.131	2.261	0.20553
31st	19 487	2.392	2.524	0.22945
32d	21 635	2.656	2.834	0.25763
33d	24 532	3.012	3.255	0.295909
34th	28 487	3.498	3.972	0.36109
35th	36 217	4.447	5.097	0.46336
36th	46 817	5.748	7.233	0.65754
37th	71 000	8.718		

Column 1 shows ten-day periods arranged in order of magnitude.
Column 2 shows the average run-off for twenty years.
Column 3 shows average run-off per square mile per second.
Column 4 shows average run-off for each pair of periods.
Column 5 shows horse-power at 80 per cent. efficiency that may be derived from one square mile on a fall of one foot for a twenty-four-hour day. The horse-power in any given case may be obtained by multiplying the averages of column 5 by the fall in feet and this product by the number of square miles of watershed.

If a ten-hour day be required, multiply the above result by two and four tenths (2.4).

A PECULIAR LEAK IN A MAIN PIPE.

BY ROBERT C. P. COGGESHALL, SUPERINTENDENT NEW BEDFORD WATER WORKS.

[*Presented December 11, 1907.*]

Mr. Coggeshall. Mr. President, I hardly know how to begin, but as we had an episode in our town recently which was certainly peculiar, and as a number of inquiries have been made to-day by those who had read of the occurrence in the daily papers, I told the president that I would briefly describe the facts in the case.

The 24th of November, Sunday, was a stormy day. The storm increased in intensity until well into the night, and the following morning it was clear. The New Haven Railroad at the present time is engaged in abolishing grade crossings through our city. About all of the streets which cross this work are now in a demoralized condition. There has been an everlasting amount of work done in the transforming of gas pipes, water pipes, electric light cables, and street-car tracks to the new level. Any one who is familiar with New Bedford will know the location of the Wamsutta Mills, which are seen on the left as you enter the town. At this point, known as Acushnet Avenue and Wamsutta Street, the railroad tracks are to cross overhead in a diagonal way. The water pipes and the gas pipes have recently been lowered to the new grade, nearly four feet below their former level.

About nine o'clock on this Sunday morning a leak was reported on the surface of the street at this crossing. The employees of the water works and of the gas company were called, and it developed that the water was issuing from a gas pipe; that there had been a break in the gas main. It was puzzling to know from whence the water came. As far as we knew, there was no connection between the water pipes and the gas pipes, and yet the water was flowing from the gas pipe in pretty large quantities. There was a possibility that a connection had established itself with a pipe belonging to the railroad company, through which they supplied themselves with

water from a source some three miles away, but that did not seem probable. A few years previous the gas company had received water in its pipes from a brook north of this location; and at this time they had recently been laying pipes beneath a couple of other brooks. Excavations were made at those places and their pipe found intact.

All this consumed the time until the beginning of the afternoon. About two o'clock in the afternoon an employee of the gas company, coming through another street fully half a mile distant from the location where water was issuing on Wamsutta Street, noticed that water was coming pretty vigorously from a drip. He went to examine it. At the same time his attention was called to a murmuring noise in the hydrant close at hand. Our employees were again notified and worked in connection with the gas company employees in making an excavation. As there was no surface indication of a leak, there was no certainty as to the proper place to excavate.

At this point the water main, 16 inches in diameter, is upon the westerly side of the street; the gas pipe, 6 inches in diameter, is located on the easterly side. A 4-inch branch from the water main runs at right angles across the top of the gas main to supply the hydrant where the noise was heard. A large section of the water piping was shut off, gradually locating the leak near to the hydrant. We then assumed that it must be near the point where the hydrant branch crossed over the gas main. A trench was then opened to the bottom of the gas pipe, which was fully a foot below the water pipe, and this trench continued on toward the point of intersection, and it was not until it was opened within one foot of that intersection that water appeared from the leak, although you could hear it. When the excavation was completed the water and gas pipe were found to lie together as shown in this photograph, (Plate I, Fig 1.) The water pipe was the top pipe, and there was about half an inch of space between that and the lower or gas pipe. So closely had something made a connection between these two pipes that very little water appeared in the excavation. It was practically as if a nipple had been inserted connecting the two pipes. After punching and probing, the water appeared and immediately filled the trench. I

FIG. 1. GAS AND WATER PIPES IN POSITIONS IN WHICH THEY LAY IN THE GROUND.

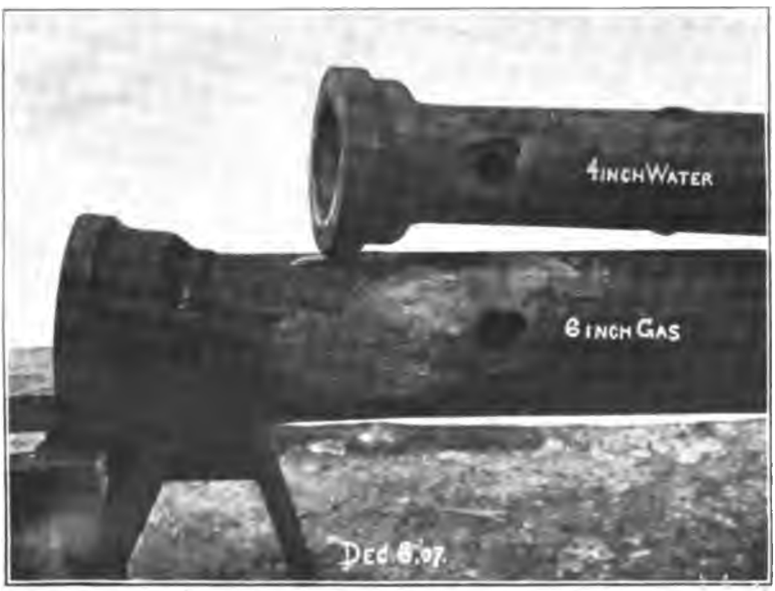


FIG. 2. HOLES IN WATER AND GAS PIPES.

wish the composition which formed this connection had been saved for our later examination, but it was all lost. The water having been shut off and the trench bailed out, the gas issued forth so strongly that all work had to be abandoned that night.

The next morning the work of repair was made. Representatives from the gas and electric light company, which are under one management, the electric railroad company, and the water department were on hand. Tests for currents were made. At that time the current was plus to the gas main, less than a volt. A volt was the maximum; about half a volt was nearer the average. The maximum amperage was 0.6, 0.4 perhaps being the average. [These figures were verified by Mr. Wm. E. Foss, who visited the location a few days later.] Later in the day the superintendent of the electric railroad caused the entire current of his system to be shut off for a few moments, and the instruments indicated a zero reading, returning to readings given above when the current was resumed. This indicated pretty conclusively that the current under measurement at that time was due to the railroad power. The superintendent of the railroad made the statement on public print upon that day that probably they were the sinners. When the pipes were taken out it was seen that holes of about the same size had been bored through both pipes. These were about $1\frac{1}{2} \times 1\frac{1}{4}$ inches in size upon the inside edge of both pipes and flaring in both cases to the outside edge of pipe. These holes have the appearance of having been melted out quickly; several pits in the iron around these holes have the appearance of having been melted. The iron in both castings is excellent and there is a complete absence of that graphite-like softness which is an indication of gradual electrolysis. It would seem that the damage must have been caused by a current of much more intensity than that which was observed as stated above.

At the present time I can offer no solution of the cause. If it was due to what is known as electrolysis, it would seem as if only one pipe would have been damaged, that is, the pipe from which the current flows. The question of reversal of current has been suggested, but there is an absence of the graphite-like formation which under such a condition should be present. A short circuit is more probable, but we have not been informed that there is other

evidence of such an occurrence. It has been suggested that changes in bonding and wiring incidental to the grade-crossing work was responsible for the cause of this incident.

The gas mains were filled with water to such an extent that the whole northerly part of the city was completely deprived of gas for several days. Over thirteen hundred meters were damaged, beside other damages caused by water and explosions. All through this section, when people tried to turn on gas, they would obtain a little jet of water. At the present time the problem is unsolved, and I don't know that I can say anything further.

MR. GEORGE A. CALDWELL. May I ask one question, Mr. Coggeshall? Possibly it may be of interest. Is it not a fact that the water came from the gas burners in the houses at a higher elevation than that of the main line of gas pipe which was broken?

MR. COGGESHALL. Oh, yes, a good deal higher; some 15 or 20 feet higher.

MR. CALDWELL. I happened to be down there at New Bedford and I went into the matter very thoroughly with both the gas company and Mr. Coggeshall, and that is something which appealed to me as a very peculiar state of affairs, — that the water should come out through the gas fixtures at a higher level than the gas main on the street; and yet they were not troubled with back pressure of water in the gas mains for only about half a mile, I will say, from the break, that is, towards the gas works.

MR. COGGESHALL. I think possibly that may be explained by the fact that this joint which Nature made was almost a tight joint, and the water pressure at that point is some 75 to 80 pounds and it was probably due to the water pressure, because the connection was almost tight.

MR. CALDWELL. In that case, why didn't they have a back pressure of water in the gas main, which was only carrying a pressure of about 3 ounces?

MR. COGGESHALL. I don't know.

PROCEEDINGS.

NOVEMBER MEETING.

HOTEL BRUNSWICK,
BOSTON, November 13, 1907.

The November meeting of the Association was held at the Hotel Brunswick, Boston, at 2 P.M., on Wednesday, November 13, 1907.

President John C. Whitney presided, and the following members and guests were in attendance:

MEMBERS.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, H. K. Barrows, J. E. Beals, George Bowers, E. C. Brooks, George Cassell, C. E. Chandler, J. C. Chase, C. E. Child, J. H. Child, W. F. Codd, R. C. P. Coggeshall, J. W. Crawford, E. D. Eldredge, J. N. Ferguson, J. H. Flynn, F. F. Forbes, F. L. Fuller, J. C. Gilbert, A. S. Glover, R. A. Hale, F. E. Hall, J. O. Hall, J. C. Hammond, Jr., H. G. Holden, E. W. Kent, Willard Kent, G. A. King, F. A. McInnes, Hugh McLean, N. A. McMillen, D. E. Makepiece, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, H. A. Miller, C. A. Mixer, William Naylor, G. A. Nelson, O. E. Parks, E. M. Peck, H. E. Royce, H. W. Sanderson, E. M. Shedd, C. W. Sherman, G. A. Stacy, J. T. Stevens, W. F. Sullivan, H. L. Thomas, R. J. Thomas, W. H. Thomas, C. A. Townsend, D. N. Tower, W. H. Vaughn, C. K. Walker, R. S. Weston, J. C. Whitney, G. E. Wilde, F. B. Wilkins, G. E. Winslow. — 63.

ASSOCIATES.

Anderson Coupling Co., by Charles E. Pratt; Ashton Valve Co., by C. W. Houghton; Harold L. Bond Co., by Harold L. Bond; Builders Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Hersey Mfg. Co., by Albert S. Glover and W. A. Hersey; International Steam Pump Co., by Sam'l Harrison; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by George A. Caldwell; National Meter Co., by Charles H. Baldwin, J. G. Lufkin and H. L. Weston; Neptune Meter Co., by Fred A. Smith and H. H. Kinsey; Pittsburg Meter Co., by F. L. Northrop; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by F. N. Whitcomb; Union Water Meter Co., by Frank E. Hall; Water Works Equipment Co., by W. H. Van Winkle. — 21.

GUESTS.

Kendall Pollard, Swampscott, Mass.; P. R. Sanders, Concord, N. H.; E. T. Harvell, Water Commissioner, Rockland, Mass.; C. N. Oakes, City Clerk, Westfield, Mass.; Amos H. Eaton, Chairman Water Commissioners, Middleboro, Mass.; Fred M. Hutchinson, Somerville, Mass.; Charles E. Dewey, Westfield, Mass.; John P. McCarthy, Member of Water Board, Lawrence, Mass., and Robert E. Newcomb, Holyoke, Mass. — 9.

[Names counted twice — 4.]

The Secretary read applications for membership from the following persons:

Harold T. Murphy, civil engineer, Springfield, Mass.; Charles E. Warren, trustee of Kennebec Water District, Waterville, Me.; G. L. Learned, trustee of Kennebec Water District, Waterville, Me.; Percy R. Sanders, superintendent of Concord Water Works, Concord, N. H.; Joseph M. Brown, chairman of water committee, East Orange, N. J., all of whom had been recommended for election by the Executive Committee.

On motion the Secretary was authorized to cast a ballot for the Association in favor of the applicants, which he did, and they were declared elected to membership.

The Secretary read a communication from the secretary of the National Municipal League, as follows:

NATIONAL MUNICIPAL LEAGUE.

PHILADELPHIA, November 6, 1907.

To the Members of the New England Water Works Association, — We take pleasure in extending to you a cordial invitation to attend an annual meeting of the National Municipal League, which will be held in conjunction with the American Civic Association, at Providence, November 19–22.

We enclose a program showing in detail the subjects that are to be considered at the meetings of these two bodies, and we especially call your attention to the joint session to be held on Friday morning, November 22, at which time the subject of " Municipal Health and Sanitation " will be considered.

Hoping that you will be able to attend these sessions, I am,

Very truly yours,

CLINTON ROGERS WOODRUFF,
Secretary.

On motion of Mr. R. C. P. Coggeshall, duly seconded, the Secretary of the Association was instructed to acknowledge the re-

ceipt of the invitation of the National Municipal League, and to thank the secretary for sending it.

Mr. Charles W. Sherman. Mr. President, those of us who were at Springfield will remember that a committee was appointed at the convention which I believe is going to do a very valuable work for the Association, a committee to compile data on damages from water diversion cases. It has recently occurred to me that a similar committee to compile data with reference to water works valuation cases would do work of equal value to the Association, and it would be a work in which perhaps a larger percentage of our members would have an active interest.

I, therefore, bring the matter before this meeting, and if it meets with favorable consideration, I will present a motion that the President appoint a committee of five to compile information relating to awards that have been made in water-works valuation cases.

It seems to be more and more common — at least in this part of the country — for municipalities to take possession of privately owned water works, and, so far as I have heard, in every such case there has been a court valuation of the works so taken, and the amount to be paid by the municipality has been decided by that award.

Very few of us see any information, or anything more than newspaper reports, of such cases, and it seems to me that there is a chance here for a committee to do a work of great value to the Association.

I would like an expression of opinion from some of the members present before I formally present that motion, if the President will allow it to come in that way; but if all of them see it as I do, I shall be glad to offer it.

The President. You have heard Mr. Sherman's remarks; is there anything to be said? We would like to have an expression of opinion from the members regarding the advisability of appointing a committee of this kind.

Mr. John C. Chase. That is a matter that has touched me in a tender spot twice within the last few months. If Mr. Sherman will put his motion, I will very heartily second it.

Mr. Sherman. In that case, Mr. President, I will formally offer the motion.

Mr. Charles A. Mixer. Mr. President, before the motion is really put, might it be made to include not only works that have been valued, but also works that shall be valued in the future?

Mr. Chase. Mr. President, I am afraid that would cut into the services of some distinguished experts who want a job. [Laughter.]

The President. I am afraid that our prophetic sense will not reach quite to that point.

(The motion, on being seconded, was put by the President, and declared to be a vote.*)

Mr. Robert E. Newcomb, M.E., Holyoke, Mass., read a paper entitled "Fire Hydrants." It was discussed by Messrs. G. A. Stacy, F. A. McInnes, E. C. Brooks, W. F. Sullivan, J. H. Flynn, R. J. Thomas, F. S. Bates, E. F. Hughes, F. L. Fuller, John C. Chase, Hugh McLean, and George Cassell.

Mr. George A. Stacy offered the following vote: Moved, that the President be authorized to appoint a committee of five to prepare a standard specification for fire hydrants.

The motion was seconded and carried.†

Mr. Charles E. Chandler, C.E., Norwich, Conn., read a paper entitled "Stream Flow Data, from a Water-Power Standpoint." It was discussed by Messrs. R. A. Hale, Charles A. Mixer, H. K. Barrows, Charles W. Sherman, and Mr. Chandler.

The meeting then adjourned.

* The President subsequently appointed the following committee: Messrs. Allen Hazen, Desmond FitzGerald, Charles A. Allen, John C. Chase, and Francis W. Dean.

† The President subsequently appointed the following committee: H. O. Lacount, George A. Stacy, Frank A. McInnes, Frederick W. Gow, and William F. Sullivan.

PROCEEDINGS.

December Meeting.

Hotel Brunswick,
Boston, December 11, 1907.

The December meeting of the Association was held at the Hotel Brunswick, Boston, at 2 P.M., Wednesday, December 11, 1907.

President John C. Whitney presided, and the following members and guests were present:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, J. E. Beals, J. W. Blackmer, C. A. Bogardus, E. C. Brooks, George Cassell, J. C. Chase, C. E. Childs, F. L. Clapp, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, C. H. Eglee, C. R. Felton, A. N. French, D. H. Gilderson, A. S. Glover, R. A. Hale, F. E. Hall, T. G. Hazard, Jr., B. B. Hodgman, J. L. Howard, E. W. Kent, Willard Kent, F. C. Kimball, G. A. King, T. H. McKenzie, Thomas McKenzie, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Mayo, F. E. Martin, William Naylor, F. L. Northrop, E. W. Shedd, C. W. Sherman, H. W. Spooner, W. F. Sullivan, R. J. Thomas, W. H. Thomas, J. A. Tilden, C. A. Townsend, W. H. Vaughn, J. C. Whitney, G. E. Winslow. — 48.

Associates.

Anderson Coupling Co., by F. A. Leavitt; Harold L. Bond Co., by Harold L. Bond; Chapman Valve Mfg. Co., by Edw. F. Hughes; Eagle Oil & Supply Co., by J. L. Hamilton; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden, W. A. Hersey; International Steam Pump Co., by Sam'l Harrison; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by George A. Caldwell; National Meter Co., by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; National Water Main Cleaning Co., by Burt B. Hodgman; Neptune Meter Co., by H. H. Kinsey; Pittsburg Meter Co., by F. L. Northrop; Rensselaer Mfg. Co., by C. L. Brown; A. P. Smith Mfg. Co., by F. N. Whitcomb; Thomson Meter Co., by E. W. Shedd; Union Water Meter Co., by Edw. P. King and F. E. Hall; United States Cast Iron Pipe & Foundry Co., by Frank W. Nevins; Water Works Equipment Co., by W. H. Van Winkle. — 24.

Guests.

James G. Hill, water commissioner, Lowell, Mass.; Baron DeWill, Paris, France; E. T. Harvell, water commissioner, Rockland, Mass.; J. F. Moore, Pascoag, R. I.; S. B. Palmer and Z. R. Robbins, Norwich, Conn.; A. E. Blackmer, Plymouth, Mass.; Arthur F. Ballou, superintendent, Woonsocket, R.

I.; Charles G. Roberts, water commissioner, Chelsea, Mass.; Charles F. Glavin, of Chas. Millar & Sons Co., Utica, N. Y.; L. H. Caufel, Boston, Mass., and F. M. Hutchinson, Somerville, Mass. — 12.

[Names counted twice — 7.]

The Secretary announced that application for membership had been received from the following-named persons, and had been properly endorsed and recommended by the Executive Committee:

Active. — J. S. Thornton, Sonora, Cal., general manager of Tuolumne County Water and Electric Power Co., Sonora, Cal.; Arthur F. Ballou, superintendent Water Department, Woonsocket, R. I.; Harry S. R. McCurdy, Brown's Station, N. Y., with New York Board of Water Supply; John F. Morse, Pascoag, N. J., with Pascoag Water Co.

Associate. — Charles Millar & Sons Co., Utica, N. Y., manufacturers of cast-iron water and gas pipe.

On motion of Mr. Chase, the Secretary was instructed to cast one ballot in favor of the candidates named, and, he having done so, they were declared by the President duly elected members of the Association.

Mr. Charles H. Eglee, hydraulic engineer, Boston, was called upon as the first speaker of the afternoon. His subject was, "Hollow Concrete-Steel Dams." At the conclusion of his remarks Mr. Eglee answered questions asked by Mr. R. C. P. Coggeshall, Mr. Wm. F. Sullivan, Mr. T. H. McKenzie, Mr. D. E. Makepeace, and Mr. Richard A. Hale.

Mr. Coggeshall told of a rather peculiar experience in New Bedford recently, where Nature had apparently in some mysterious way established a connection between a gas main and a water main which were about half an inch apart, and the gas pipes in a large section of the city had been filled with water.

In response to an inquiry by the President as to a good method of protecting water pipes over bridges from frost, Mr. Coggeshall and Mr. Frank L. Fuller advised boxing and an air space.

Mr. H. W. Spooner, engineer of the Gloucester Water Works, showed some excellent lantern slides of views on Cape Ann and at Magnolia and of mackerel fishing operations.

Adjourned.

EXECUTIVE COMMITTEE.

TREMONT TEMPLE, BOSTON, MASS.,
Wednesday, November 13, 1907, 11.30 A.M.

Present: President John C. Whitney, and L. M. Bancroft, George A. King, Robert J. Thomas, Charles W. Sherman, and Willard Kent.

The following applications, five in number, were received and recommended for membership in the Association:

Harold T. Murphy, Springfield, Mass.; Charles E. Warren, Waterville, Me.; G. L. Learned, Waterville, Me.; Percy R. Sanders, Concord, N. H.; Joseph M. Brown, East Orange, N. J.

Voted: That "The Liberty Trust Company" be and hereby is approved as a place of deposit for a portion of the funds of this Association.

Voted: That the Treasurer, President, and Editor be a committee on the investment of the funds of the Association, to investigate and report at the next meeting of the Executive Committee.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

TREMONT TEMPLE, BOSTON, MASS.,
December 11, 1907.

Present: Vice-President George A. King, presiding; Charles W. Sherman, Robert J. Thomas, L. M. Bancroft, A. E. Martin, Willard Kent.

The following applications were received and recommended for membership:

Members: John F. Moore, Pascoag, R. I.; Harry S. R. McCurdy, Brown's Station, N. Y.; Arthur F. Ballou., Woonsocket, R. I.; J. S. Thornton, Sonora, Cal.

Associate: Charles Miller & Son Co., manufacturers of cast-iron water and gas pipe, Utica, N. Y.

The Secretary was instructed to investigate the advisibility of having the expense of room for the monthly meetings charged to the Association, if a corresponding reduction can be made in the price of the dinner tickets.

The Treasurer reported progress of the work of the Committee on Investment.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

ARTHUR J. L. LORETZ, mechanical engineer, of 397 Ninth Street, Brooklyn, N. Y., died May 27, in California. He was born in the Province of Alsace, then France, and was the youngest son of the late Prof. J. B. Loretz, of Brooklyn. He was intimately associated with the pumping engine trade for years, was an inventor, patented the national steam pumps and pumping engines, was awarded three medals in 1875–6 for these pumps by the American Institute of New York, New Jersey, and Philadelphia, and numerous diplomas. Has been consulting engineer for large manufacturing plants. Mr. Loretz became a member of the New England Water Works Association on December 9, 1896.

TRADE PUBLICATIONS.

Allis-Chalmers Company, Pumping Engine Department, Bulletin No. 1610. August, 1907.

Allis-Chalmers Vertical Tandem-Compound Screw Pumping Engine, built for the Kinnickinnic Flushing Tunnel, Milwaukee, Wis.

This bulletin describes the screw pumping engine, with a capacity of 323,000 000 gallons per day, lifted 3½ feet, by which Lake Michigan water is pumped into the Kinnickinnic River for flushing purposes.

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JOURNAL

OF THE

New England Water Works Association.

ISSUED QUARTERLY.

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THE NEW ENGLAND WATER WORKS ASSOCIATION.

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OFFICERS

OF THE

New England Water Works Association.

1907.

THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of nearly 700 men. Its membership is divided into two principal classes, viz.: MEMBERS and ASSOCIATES. Members are divided into two classes, viz.: RESIDENT and NON-RESIDENT, — the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter, THREE dollars. The annual dues for both classes of Active membership are THREE dollars. Associate membership is open to firms or agents of firms engaged in dealing in water works supplies. The initiation fee for Associate membership is TEN dollars, and the annual dues FIFTEEN dollars. This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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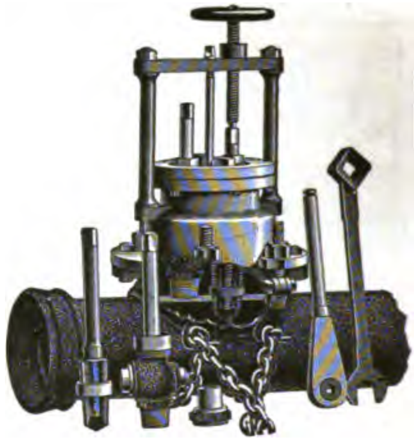

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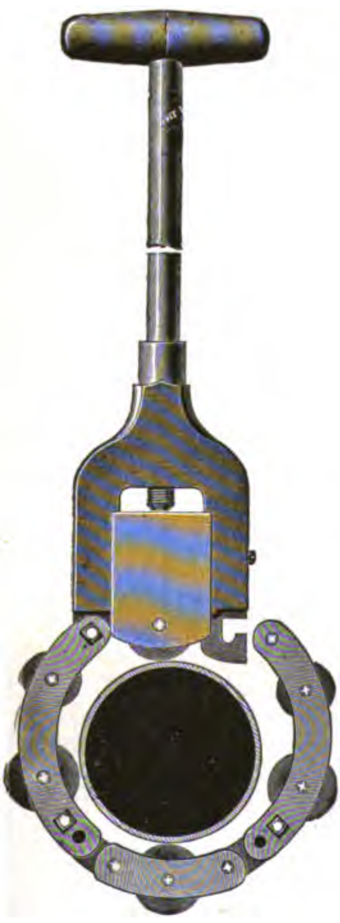

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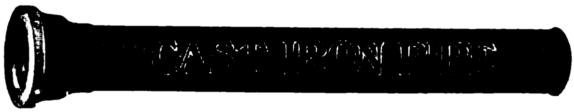

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The Journal of the New England Water Works Association

is a quarterly publication, containing the papers read at the meetings, together with verbatim reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness. ALL MEMBERS OF THE ASSOCIATION RECEIVE THE JOURNAL IN PART RETURN FOR THEIR ANNUAL DUES; to all others the subscription is three dollars per annum.

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